United States
Department of
Agriculture

Agricultural
Research
Service

ARS-25

December 1985

Hydrology and Hydrogeology of Upper Taylor Creek Watershed, Okeechobee County, Florida: Data and Analysis

Knisel, W. G., Jr.; Paul Yates; J. M. Sheridan; T. K. Woody, III; L. H. Allen, Jr.; and L. E. Asmussen. 1985. Hydrology and Hydrogeology of Upper Taylor Creek Watershed, Okeechobee County, Florida: Data and Analysis. U.S. Department of Agriculture, Agricultural Research Service ARS–25,159 pp.

The authors are with the U.S. Department of Agriculture, Agricultural Research Service, Southeast Watershed Research Program, Athens and Tifton, Ga., and Gainesville, Fla.

The research reported in this publication was done in cooperation with the U.S. Department of Agriculture, Soil Conservation Service; the U.S. Geological Survey; the South Florida Water Management District; and the University of Florida Agricultural Experiment Station.

Copies of this publication may be purchased from:
National Technical Information Service
5285 Port Royal Road
Springfield, Va. 22161
The Agricultural Research Service has no additional copies for free distribution.

United States
Department of
Agriculture

**Agricultural
Research
Service**

ARS-25

December 1985

Hydrology and Hydrogeology of Upper Taylor Creek Watershed, Okeechobee County, Florida: Data and Analysis

Prepared by W. G. Knisel, Jr.; Paul Yates;
J. M. Sheridan; T. K. Woody, III;
L. H. Allen, Jr.; and L. E. Asmussen

Acknowledgments

The authors gratefully acknowledge the cooperation and personal assistance of numerous individuals throughout the study on which this publication is based. Personnel in cooperating agencies were involved in data collection and supplied information necessary to assemble and analyze data and to interpret and report the findings. The following agencies and individuals are recognized: (1) Soil Conservation Service: W. E. Austin, R. M. Craig, W. R. McCall; (2) U.S. Geological Survey: J. C. Kimrey, R. A. Bird; (3) Central and Southern Florida Flood Control District: G. E. Dail, Jr., R. L. Taylor, R. L. Hamrick, W. V. Storch (deceased); (4) Florida Agricultural Experiment Station (FAES): J. F. Gerber, J. W. Sites, D. V. Calvert, B. L. James; and (5) Agricultural Research Service: J. C. Stephens, W. C. Mills, W. M. Snyder, R. B. Slack, C. A. Burroughs, J. D. Dean, M. J. Murphy, B. W. Scarborough, O. S. McMillan, M. L. Hester, H. L. Batten, H. Henry, R. Leaders, H. D. Allison, E. H. Stewart, H. D. Wade, R. R. Alberts, W. H. Speir (deceased), J. E. Browning (deceased), A. Sullivan, K. K. Steward.

The authors realize that individuals other than those listed above contributed to the overall project. Also, the long time frame of the project was such that personnel changes occurred over the years, and some names were possibly inadvertently overlooked.

J. C. Stephens, former director of watershed research at Fort Lauderdale, Fla., is acknowledged for his efforts in initiating the study.

Mr. Arthur Raulerson (deceased) is acknowledged for his painstaking efforts in obtaining climatological data at raingage 3 over the lifespan of the project.

Contents

Acknowledgments ii
Preface x
Significant developments and findings xi

Sec.

1. Introduction 1
- 1.1. Study plan 1
  - 1.1.1. General purpose 2
  - 1.1.2. Procedures 2
  - 1.1.3. Cooperators' responsibilities 2
  - 1.1.4. Data-collection responsibilities 2
- 1.2. Watershed 3
  - 1.2.1. Location 3
  - 1.2.2. Geology and soils 4
  - 1.2.3. Fluvial geomorphology 5
    - 1.2.3.1. Physiographic setting 5
    - 1.2.3.2. Geomorphic interpretations 5
  - 1.2.4. Topography and surface drainage 9
  - 1.2.5. Land use 10
  - 1.2.6. Climate 10

2. Data Available 12
- 2.1. Precipitation 12
- 2.2. Streamflow 12
- 2.3. Ground water 13
- 2.4. Temperature and evaporation 13
- 2.5. Water quality 14

3. Precipitation Representativeness 14
- 3.1. Annual data for record period 14
- 3.2. Monthly data 15
  - 3.2.1. Record period 15
  - 3.2.2. Treatment periods 16

4. Data Summarization 18
- 4.1. Precipitation 18
  - 4.1.1. Frequency of daily precipitation 18
  - 4.1.2. Areal distribution of precipitation 20
  - 4.1.3. Storm-rainfall duration 22
  - 4.1.4. Time distribution of storm rainfall 22
  - 4.1.5. Climatic drought 27
  - 4.1.6. Probabilities of 5-day precipitation 30
- 4.2. Streamflow 30
  - 4.2.1. Streamflow duration 30
  - 4.2.2. Minimum streamflow frequency 33
  - 4.2.3. Flood-flow frequency 35
  - 4.2.4. Streamflow volume frequency 36
- 4.3. Ground water 38
  - 4.3.1. Effects of channelization and water-level control structures 38
    - 4.3.1.1. Observation-well networks 38
    - 4.3.1.2. Ground-water profile adjacent to a channel 43
  - 4.3.2. Ground-water duration 46
    - 4.3.2.1. Daily duration 46
    - 4.3.2.2. 5-, 10-, and 30-day durations 48
  - 4.3.3. Maximum and minimum 5-day ground-water elevations 57
  - 4.3.4. Moving averages 57

5. Analyses and Interpretations 70
- 5.1. Water-yield analyses 70
  - 5.1.1. Annual precipitation and streamflow 70
  - 5.1.2. 4-month precipitation and streamflow 72
  - 5.1.3. Monthly precipitation and streamflow 77
- 5.2. Storm analysis 78
  - 5.2.1. Streamflow response to precipitation 79
  - 5.2.2. Ground-water response to precipitation 86
    - 5.2.2.1. Ground-water fluctuations 86
    - 5.2.2.2. Ground-water hydrograph 88
  - 5.2.3. Streamflow and ground-water simulation 92
- 5.3. Recession analysis 94
  - 5.3.1. Streamflow 94
  - 5.3.2. Ground-water recessions 95
- 5.4. Evapotranspiration 97
  - 5.4.1. Annual data 100
  - 5.4.2. Monthly and seasonal data 103
- 5.5. Water quality 106
  - 5.5.1. Streamflow 106
  - 5.5.2. Plant nutrients 109
    - 5.5.2.1. Nitrate nitrogen 109
    - 5.5.2.2. Orthophospate phosphorus 111
  - 5.5.3. Chloride 112

Literature Cited 114
Appendix.—Data Summary 117

Illustrations

Fig.

1.1. Major land resource areas of the Southeast 4
1.2. Location of Taylor Creek watershed in south Florida 4
1.3. Upper Taylor Creek watershed W–2 4
1.4. Upper Taylor Creek watershed W–2, showing subwatersheds W–3 and W–5 5
1.5. General soil map of Okeechobee County, Fla., showing soil associations in Taylor Creek watershed 6
1.6. Hypsometric curve, subwatershed W–3 8
1.7. Hypsometric curve, watershed W–2 8
1.8. Water-table hypsometric curve, watershed W–2 8
1.9. Longitudinal profile of main stem, Taylor Creek 9
1.10. Topographic map, Upper Taylor Creek watershed 9
1.11. Mean monthly temperatures, Okeechobee hurricane gate 6, 1919–71 11
1.12. Mean monthly rainfall, Okeechobee hurricane gate 6, 1919–71 11
3.1. Histogram of annual rainfall, Okeechobee hurricane gate 6, 1930–70 14
3.2. Histogram of annual rainfall, Okeechobee hurricane gate 6, 1956–70 15
3.3. Monthly maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 15
3.4. Mean 2-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 16
3.5. Mean 3-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 16
3.6. Mean 4-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 16
3.7. Mean 5-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 17
3.8. Mean 6-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71 17
3.9. Monthly rainfall, Okeechobee hurricane gate 6, 1955–72 17
3.10. Mean monthly 2-month rainfall, Okeechobee hurricane gate 6, 1955–72 17
4.1. Observed and calculated histograms for monthly minimum daily rainfall, Okeechobee hurricane gate 6, 1930–72 20
4.2. Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, January 20
4.3. Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, April 20
4.4. Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, July 21
4.5. Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, October 21
4.6. Relationship between ratio of area-to-point rainfall and size of area, Taylor Creek watershed 22
4.7. Time-distribution curves representing usual patterns for high-intensity rainfall 25
4.8. Observed and calculated histograms for summer-storm rainfall, rain-gage 4 26
4.9. Observed and calculated histograms for winter-storm rainfall, rain-gage 4 26
4.10. Observed histograms of drought duration, Okeechobee hurricane gate 6 29
4.11. Flow-duration curves, watershed W–2 and subwatershed W–3 before channelization 32
4.12. Flow-duration curves, watershed W–2 before and after channelization 32
4.13. Flow-duration curves, subwatershed W–3 before and after channelization 33
4.14. Flow-duration curves, subwatershed W–5 after channelization 33
4.15. Flow-duration curves, watershed W–2 and subwatersheds W–3 and W–5 after channelization 34
4.16. Frequency of 7-, 14-, and 30-day minimum discharge, watershed W–2 34
4.17. Frequency of instantaneous and mean daily peak discharges, watershed W–2 35
4.18. Frequency of instantaneous and mean daily peak discharges, subwatershed W–3 36
4.19. Frequency of streamflow volumes for periods of 6 and 12 hours and 1, 2, and 8 days, watershed W–2 37
4.20. Frequency of streamflow volumes for periods of 6 and 12 hours and 1, 2, and 8 days, subwatershed W–3 37
4.21. Mean monthly depth of ground water, well 1 39
4.22. Mean monthly depth of ground water, well 2 39
4.23. Mean monthly depth of ground water, well 3 40
4.24. Mean monthly depth of ground water, well 4 40
4.25. Mean monthly depth of ground water, well 5 41

4.26. Mean monthly depth of ground water, well 6 . 41
4.27. Mean monthly depth of ground water, well 7 . 41
4.28. Mean monthly depth to ground water, average of wells 1 and 2, subwatershed W–3 42
4.29. Mean monthly depth to ground water, average of wells 1–7, watershed W–2 42
4.30. Mean monthly depth to ground water, average of wells 6 and 7 (1959–68) and well 7 only (1967–73), subwatershed W–5 43
4.31. Mean monthly ground-water elevations for three selected wells, well-line A 43
4.32. Ground-water surface profiles, before and after channelization, well-line A 44
4.33. Mean monthly ground-water elevations for recorder well, well-line B 45
4.34. Mean monthly ground-water elevations for well at 2,000-foot location, well-line B 45
4.35. Water-surface profiles, before channelization, well-line B 45
4.36. Ground-water duration, before and after channelization, well 1 46
4.37. Ground-water duration, before and after channelization, well 2 47
4.38. Ground-water duration, before and after channelization, well 3 47
4.39. Ground-water duration, before and after channelization, well 4 47
4.40. Ground-water duration, before and after channelization, well 5 47
4.41. Ground-water duration, before and after channelization, well 7 48
4.42. Annual cycle of ground-water elevation, 5-day averages for entire record period, wells 1, 2, and 3, 1960–73 57
4.43. Annual cycle of ground-water elevation, 5-day averages for entire record period, wells 4, 5, and 7, 1960–73 57
4.44. Annual cycle of ground-water elevation, 5-day averages for period before channelization, wells 1, 2, and 3, 1960–63................. 58
4.45. Annual cycle of ground-water elevation, 5-day averages for period before channelization, wells 4, 5, and 7, 1960–63................. 58
4.46. Annual cycle of ground-water elevation, 5-day averages for period before channelization, well 6, 1960–63 59
4.47. Annual cycle of ground-water elevation, 5-day averages for period after channelization, wells 1, 2, and 3, 1969–72...................... 59
4.48. Annual cycle of ground-water elevation, 5-day averages for period after channelization, wells 4, 5, and 7, 1969–72...................... 60
4.49. Median 5-, 10-, and 30-day ground-water elevations, well 1, 1960–73 60
4.50. Median 5-, 10-, and 30-day ground-water elevations, well 2, 1960–73 61
4.51. Median 5-, 10-, and 30-day ground-water elevations, well 3, 1960–73 61
4.52. Median 5-, 10-, and 30-day ground-water elevations, well 4, 1960–73 62
4.53. Median 5-, 10-, and 30-day ground-water elevations, well 5, 1960–73 62
4.54. Median 5-, 10-, and 30-day ground-water elevations, well 6, 1960–73 63
4.55. Median 5-, 10-, and 30-day ground-water elevations, well 7, 1960–73 63
4.56. Median 5-, 10-, and 30-day ground-water elevations, well 1, 1960–63 64
4.57. Median 5-, 10-, and 30-day ground-water elevations, well 2, 1960–63 64
4.58. Median 5-, 10-, and 30-day ground-water elevations, well 3, 1960–63 65
4.59. Median 5-, 10-, and 30-day ground-water elevations, well 4, 1960–63 65
4.60. Median 5-, 10-, and 30-day ground-water elevations, well 5, 1960–63 66
4.61. Median 5-, 10-, and 30-day ground-water elevations, well 6, 1960–63 66
4.62. Median 5-, 10-, and 30-day ground-water elevations, well 7, 1960–63 67
4.63. Median 5-, 10-, and 30-day ground-water elevations, well 1, 1969–72 67
4.64. Median 5-, 10-, and 30-day ground-water elevations, well 2, 1969–72 68
4.65. Median 5-, 10-, and 30-day ground-water elevations, well 3, 1969–72 68
4.66. Median 5-, 10-, and 30-day ground-water elevations, well 4, 1969–72 69
4.67. Median 5-, 10-, and 30-day ground-water elevations, well 5, 1969–72 69
5.1. Annual precipitation and streamflow, watershed W–2.................................... 70
5.2. Annual precipitation and streamflow, subwatershed W–3 70
5.3. Annual precipitation and streamflow, subwatershed W–5 70
5.4. Relationship between annual precipitation and streamflow volumes, watershed W–2......... 71
5.5. Relationship between annual precipitation and streamflow volumes, subwatershed W–3 71

5.6. Relationship between annual precipitation and streamflow volumes, subwatershed W–5 71
5.7. Relationship between precipitation and streamflow volumes, watershed W–2 before, during, and after channelization, February–May 73
5.8. Relationship between precipitation and streamflow volumes, watershed W–2 before, during, and after channelization, June–September 73
5.9. Relationship between precipitation and streamflow volumes, watershed W–2 before, during, and after channelization, October–January 74
5.10. Relationship between precipitation and streamflow volumes, subwatershed W–3 before, during, and after channelization, February–May 74
5.11. Relationship between precipitation and streamflow volumes, subwatershed W–3 before, during, and after channelization, June–September 74
5.12. Relationship between precipitation and streamflow volumes, subwatershed W–3 before, during, and after channelization, October–January 76
5.13. Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, February–May 76
5.14. Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, June–September 76
5.15. Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, October–January 76
5.16. Relationship between average precipitation and streamflow volumes by 4-month seasons, watersheds W–2, W–3, and W–5 77
5.17. Monthly rainfall and streamflow, watershed W–2, 1956–63 77
5.18. Monthly rainfall and streamflow, watershed W–2, 1969–72 77
5.19. Monthly rainfall and streamflow, subwatershed W–3, 1956–63 77
5.20. Monthly rainfall and streamflow, subwatershed W–3, 1965–72 78
5.21. Improved grass and clover pastures under 2 or more feet of floodwater, Taylor Creek watershed, October 1956 78
5.22. Inundated U.S. Highway 441 at juncture with Taylor Creek, October 1956 78
5.23. Residential flooding, Okeechobee, Fla., October 1956 78
5.24. Watershed retention function 79
5.25. Watershed characteristic function 80
5.26. Computed and observed hydrographs, subwatershed W–3 before channelization 82
5.27. Computed and observed hydrographs, subwatershed W–3 after channelization 83
5.28. Unitized characteristic functions, subwatershed W–3 before and after channelization 84
5.29. Simulated hydrographs from synthetic rainfall events, subwatershed W–3 85
5.30. Ground-water and stream-stage response to rainfall, low water-table conditions 87
5.31. Ground-water and stream-stage response to rainfall, high water-table conditions 87
5.32. Schematic of model for ground-water hydrograph analysis 89
5.33. Ground-water characteristic function 90
5.34. Computed and observed ground-water hydrographs, well 1 92
5.35. Schematic of model for discharge hydrograph and ground-water hydrograph simulation 93
5.36. Simulated storm and ground-water hydrographs, subwatershed W–3 and well 1, storm of June 17, 1971 93
5.37. Parameter b versus first-day volume V_1, watershed W–2 94
5.38. Derived values of the five parameter values defining the characteristic function for watershed W–2 95
5.39. Correspondence of calculated and observed volumes for streamflow recession of 13 days, watershed W–2 96
5.40. Correspondence of calculated and observed volumes for streamflow recession of 16 days, watershed W–2 96
5.41. Parameter b versus first-day stage, S_1, well 1 96
5.42. Parameters 2, 3, and 4 versus first-day stage, S_1, well 1 97
5.43. Correspondence of calculated and observed values of recession stages, well 4 98
5.44. Correspondence of calculated and observed values of recession stages, well 7 98

5.45. Composite moisture absorption and desorption curves characteristic of the soils, watersheds W-2 and W-3 98
5.46. Relationship between depth to water table and available water in the soil profile, watersheds W-2 and W-3 99
5.47. Ground-water contours for low-water-table conditions, watersheds W-2 and W-3 100
5.48. Ground-water contours for high-water-table conditions, watersheds W-2 and W-3 101
5.49. Mean monthly evapotranspiration, pan evaporation, radiation, and temperature, watersheds W-2 and W-3, January 1959–December 1973 104
5.50. Boundary map of watershed W-2 and subwatersheds used in water-quality study 107
5.51. Quarterly unit streamflow, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 109
5.52. Quarterly unit nitrate-nitrogen loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 109
5.53. Quarterly weighted nitrate-nitrogen concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 110
5.54. Quarterly unit orthophosphate-phosphorus loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 111
5.55. Quarterly weighted orthophosphate-phosphorus concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 111
5.56. Quarterly unit chloride loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 112
5.57. Quarterly weighted chloride concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975 112

Tables

1.1. Thiessen-weighted precipitation, by percentage, for Upper Taylor Creek watershed 3
1.2. Drainage areas and discharge conversion factors for gaging sites on Upper Taylor Creek watershed 3
1.3. Percentage of each soil association in watershed W-2 and subwatersheds W-3 and W-5 5
1.4. Stream geomorphic characteristics of watershed W-2 and subwatershed W-3 7
1.5. Land-use results for watershed W-2 and subwatershed W-3 10
4.1. Optimized and interpolated values of parameters *a*, *k*, and *m* for monthly maximum daily rainfall, Okeechobee hurricane gate 6 19
4.2. Monthly number of storms by duration, rain-gage 4, July 1955–December 1974 23
4.3. Monthly number of storms with rainfall ≥1.0 inch by duration, rain-gage 4, July 1955–December 1974 24
4.4. Optimum values of mathematical coefficients *b* and *C* and parameter *m* and values of correlation coefficient for each season, rain-gage 4 25
4.5. Rainfall of fifty 12-hour synthetic summer storms at 1-hour intervals, rain-gage 4 27
4.6. Rainfall of fifty 12-hour synthetic winter storms at 1-hour intervals, rain-gage 4 28
4.7. Schematic for seasonally continuous interpolation of bimonthly parameters in log-normal frequency distribution 29
4.8. Probabilities (percent) for consecutive days with less than 0.25 inch of daily rainfall by bimonthly period 30
4.9. Probability of precipitation greater than various amounts for each of seventy-three 5-day periods, Okeechobee hurricane gate 6 31
4.10. Periods of flow-duration analysis by watershed 31
4.11. Estimated recurrence values from fitting log-normal and log-Pearson III distributions and the percentages of difference in those values 36
4.12. Runoff volume, in inches, for selected time intervals and return periods for watershed W-2 and subwatershed W-3 38
4.13. Well duration for entire record period, beginning January 1, period 1, 1960–73 49
4.14. Well duration for entire record period, beginning April 1, period 19, 1960–73 50
4.15. Well duration for entire record period, beginning July 1, period 38, 1960–73 51
4.16. Well duration for entire record period, beginning October 1, period 56, 1960–73 52
4.17. Well duration for period before channelization, beginning January 1, period 1, 1960–63 53
4.18. Well duration for period before channelization, beginning April 1, period 19, 1960–63 53
4.19. Well duration for period before channelization, beginning July 1, period 38, 1960-63 54
4.20. Well duration for period before channelization, beginning October 1, period 56, 1960–63 54
4.21. Well duration for period after channelization, beginning January 1, period 1, 1969–72 55
4.22. Well duration for period after channelization, beginning April 1, period 19, 1969–72 55

4.23. Well duration for period after channelization, beginning July 1, period 38, 1969–72 56
4.24. Well duration for period after channelization, beginning October 1, period 56, 1969–72 56
5.1. Periods of rainfall-streamflow analysis by watershed 73
5.2. Precipitation-streamflow relationships for the 4-month seasons 75
5.3. Selected storms and associated rainfall and streamflow volumes for hydrograph analysis, subwatershed W–3 81
5.4. Optimized values of parameters and correlation coefficients for streamflow-response model before and after channelization, subwatershed W–3.................................... 82
5.5. Selected storms and associated rainfall volumes and depths to ground water for ground-water hydrograph analysis 91
5.6. Optimized values of parameters and correlation coefficient for ground-water response model .. 91
5.7. Available water in the soil profile as a composite of soils in watershed W–2 and subwatershed W–3 99
5.8. Annual precipitation, streamflow, ground-water storage, soil-water storage, and evapotranspiration, in inches, for watershed W–2 102
5.9. Annual precipitation, streamflow, ground-water storage, soil-water storage, and evapotranspiration, in inches, for subwatershed W–3 103
5.10. Mean monthly and annual evapotranspiration, pan evaporation, and radiation; mean monthly temperature; and ratio of monthly average evapotranspiration to monthly average pan evaporation for January 1959–December 1973 105
5.11. Concentrations of selected elements in samples collected from streams near Taylor Creek runoff gaging stations for comparison with samples from an artesian well in the Floridan aquifer.................................. 106
5.12. Water-quality analyses of samples collected from three open channels in Taylor Creek watershed for comparison with samples from an artesian well in the Floridan aquifer....... 107
5.13. Quarterly and annual rainfall and streamflow, in inches, for watersheds W–3, W–13, W–5, and W–2 108
5.14. Percentage of total watershed area for and of total annual discharge from subwatersheds W–3, W–13, and W–5 109
5.15. Percentages of total watershed area and annual nitrate-nitrogen loads, percentage each represents of total annual load, and ratios for subwatersheds W–3, W–13, and W–5 110
5.16. Percentages of total watershed area and annual orthophosphate-phosphorus loads, percentage each represents of total annual load, and ratios for subwatersheds W–3, W–13, and W–5..... 111
5.17. Percentages of total watershed area and annual chloride loads, percentage each represents of total annual load, and ratios for subwatersheds W–3, W–13, and W–5 113
A–1. Soil descriptions, erosion classes, and land capability classes, watershed W–2 117
A–2. Soil descriptions, erosion classes, and land capability classes, subwatershed W–3 117
A–3. Monthly and annual precipitation, in inches, for Okeechobee hurricane gate 6 118
A–4. Monthly maximum daily rainfall, in inches, for Okeechobee hurricane gate 6 120
A–5. Monthly and annual rainfall, in inches, for watershed W–2.......................... 121
A–6. Monthly and annual rainfall, in inches, for subwatershed W–3....................... 122
A–7. Monthly and annual rainfall, in inches, for subwatershed W–5....................... 122
A–8. Monthly and annual maximum rainfall, in inches, by selected time intervals, rain-gage 3, 1961–75 123
A–9. Monthly maximum daily rainfall, in inches, for rain-gage 3 128
A–10. Upper Taylor Creek watershed improvement works 129
A–11. Monthly and annual streamflow, in inches, for watershed W–2.......................... 130
A–12. Monthly and annual streamflow, in inches, for subwatershed W–3....................... 131
A–13. Monthly and annual streamflow, in inches, for subwatershed W–5....................... 132
A–14. Annual maximum peak discharge rates and volumes by selected time intervals, watershed W–2.................................. 133
A–15. Annual maximum peak discharge rates and volumes by selected time intervals, subwatershed W–3 133
A–16. Annual maximum peak discharge rates and volumes by selected time intervals, subwatershed W–5 134
A–17. Monthly maximum mean daily discharge, in cubic feet per second, for watershed W–2 ... 134

A-18. Monthly maximum mean daily discharge, in cubic feet per second, for subwatershed W-3 . 135
A-19. Monthly maximum mean daily discharge, in cubic feet per second, for subwatershed W-5 . 135
A-20. Mean monthly ground-water levels below ground surface, in feet, for watershed W-2 . . . 136
A-21. Mean monthly ground-water levels below ground surface, in feet, for subwatershed W-3 136
A-22. Mean monthly ground-water levels below ground surface, in feet, for subwatershed W-5 137
A-23. Mean monthly depth to ground water, in feet, for observation wells and recorder wells 138
A-24. Mean monthly ground-water elevations, in feet, for 104- and 535-foot well locations on lines A and B and 2,000-foot location on line B 143
A-25. Monthly and annual evaporation, in inches, for rain-gage 3 145
A-26. Mean monthly temperatures (°F) for Okeechobee hurricane gate 6, 1919–71 146
A-27. Mean monthly maximum and minimum temperatures (°F) for Okeechobee hurricane gate 6, 1919–71 147
A-28. Results of water-quality analyses on samples from various locations in watershed W-2 149
A-29. Nitrate-nitrogen (N) and orthophosphate-phosphorus (P) concentrations (mg/l), Taylor Creek watershed, 1974 153
A-30. Electrical conductivity (EC, μmhos/cm) and pH, Taylor Creek watershed, 1974 154
A-31. Nitrate-nitrogen (N) and orthophosphate-phosphorus (P) concentrations (mg/l), Taylor Creek watershed, 1975 156
A-32. Electrical conductivity (EC, μmhos/cm) and pH, Taylor Creek watershed, 1975 158

Preface

The research on which this publication is based was a cooperative effort among the U.S. Agricultural Research Service, the U.S. Soil Conservation Service, the U.S. Geological Survey, the Central and Southern Florida Flood Control District, and the Florida Agricultural Experiment Station. The responsibilities of each agency are given in the "Introduction" section. The primary purpose of the research was to collect, analyze, and interpret hydrologic data to determine the hydrologic characteristics of Upper Taylor Creek watershed under untreated conditions.

Although the Agricultural Research Service was responsible for interpreting, analyzing, summarizing, and publishing the data, significant input, review, and discussion were given by the cooperative agencies. The complexity of the project was such that the program could not have been accomplished by any single agency.

Inasmuch as the Agricultural Research Service was responsible for analyses and interpretations, expertise necessary to accomplish the intended purposes was drawn upon from the combined staffs of the Southeast Watershed Research Program, Athens and Tifton, Ga., and Gainesville, Fla.

A philosophy was developed to provide an orderly and meaningful presentation of the data, analyses, and interpretations. The general philosophy was to provide users with a complete package that would include all phases and interrelations of the project. Details of methodology were not included, for sake of brevity. However, all methodologies are adequately referenced to provide interested readers with necessary details.

This publication is divided into five main sections. The "Introduction" describes the formulation of the project, outlines the study, and gives the watershed physical characteristics, including that information provided by one-time or survey-type data. "Data Available" describes the data that were available and references the various data summaries in the appendix. "Precipitation Representativeness" considers precipitation normalcy of record periods. "Data Summarization" provides the first level of information from the time-dependent data. "Analyses and Interpretations" includes information on hydrologic component interrelations and hydrologic, geohydrologic, and water-quality inferences.

It was virtually impossible to adequately summarize the contents of such a comprehensive report. For this reason, a brief summation of the most significant findings is presented. *Users are cautioned to exercise care in taking excerpts out of context, lest misuse and misinterpretations result.*

Each development or finding is appropriately referenced in the "References" section, which contains only those references cited in the text of the report.

The authors desire to provide the most useful information possible. We recognize that any publication may well fall short of specific needs for various reasons. If any user of this publication needs supplemental information, he or she should contact the authors.

During the course of this research and while the manuscript was being prepared, several changes in State and Federal organizations occurred. In some portions of this publication, the name is given for the organization that existed at the time of the action, for example, the original memorandum of understanding between the Agricultural Research Service and the Central and Southern Florida Flood Control District (now the South Florida Water Management District). In other instances, the present organizational name is used throughout.

Development of a meaningful summary of this study in a few short paragraphs was virtually impossible. Therefore, the most significant findings in the study are presented in this section for ready reference by the user.

Methods, techniques, and mathematical models were developed in previous studies and during this study to glean the most information and inferences from the data. These methods and models are significant within themselves, and they were conceptualized as a means to factor and express information in orderly steps. The significant developments are given below. The technologies are important for application in other analyses in the future and are not limited to the Upper Taylor Creek watershed study. The models are (1) the ground-water hydrograph model: the development of a parametric model to analyze phreatic ground-water hydrographs; the model consists of characteristic function and state function (sec. 5.2.2.2); and (2) the combined storm hydrograph and ground-water hydrograph models: these models were cast into the simulation mode to predict streamflow hydrograph and ground-water recharge and depletion from rainfall using optimized parameters (sec. 5.2.3).

Several significant findings and inferences were abstracted from the Upper Taylor Creek watershed study. Realistically, the quantitative results are unique to this watershed. However, inferences can be made as to possible hydrologic characteristics of other similar watersheds with similar treatment and climatic conditions. When the hydrologic study was originally implemented in 1955, the Soil Conservation Service received a request from local sponsors for assistance in channel improvements. Storm-water drainage and water yield were primary interests at that time, and a minimal hydrologic network was designed; however, over the years emphasis changed. Instrumentation remained relatively unchanged with the exception of that involved with construction and operation of water-level control structures. The instrumentation and structure operation was less effective towards meeting new objectives. Water-quality information, collected only in the later years, was simply a survey of existing conditions to gain insight into the problems. However, these studies enabled determinations and inferences to be made, some of which are significant, about facets other than the original design. The more significant findings are given below and must be considered conditioned by the data.

Ground-water duration analysis showed that the existing channel system and associated water-level control structures raised the water table approximately 0.4 foot in the flat midreaches of Upper Taylor Creek watershed, which is in the Talbott Terrace. Lesser effects resulted in the Penholoway Terrace on the flat divides (sec. 4.3.2.2).

Channel improvement and water-level control structures had negligible effect on ground-water recharge and drainage. Mean monthly depths to ground water were approximately the same before and after treatment. At those locations within Upper Taylor Creek watershed where ground water was at the ground surface during some years before treatment, ground water rose to the ground surface during some years after treatment. Therefore, watershed treatment had negligible effect on recharge. Likewise, mean monthly depths to ground water during prolonged dry periods were approximately the same before and after watershed treatment, indicating negligible excess drainage (sec. 4.3.1.1).

Ground-water observation wells extending at a right angle to the channel and at distances of 10 to 2,000 feet from it showed minimal effects before and after watershed treatment. Water-surface profiles were similar before and after treatment during both wet and dry conditions. Reverse slopes of profiles near the channel during periods of high streamflow indicated recharge of bank storage before and after treatment. (Effects of channelization and water-level control structures on ground-water levels are limited to a distance equal to or less than 535 feet from the channel, which represents only 6 percent of the watershed area (sec. 4.3.1.2)).

Annual water-yield analysis showed some effect of channelization. Although rainfall and streamflow varied considerably from year to year, there was a slight increase in yield after treatment at subwatershed W–3 and a decrease in yield after treament at watershed W–2 (sec. 5.1.1).

Storm hydrograph analysis was limited to subwatershed W–3 because of lower relative quality of data for streamflow in watershed W–2 after treatment. Storm hydrograph model parameters were not significantly different before and after treatment when the change in drainage area was considered. Comparisons of simulated hydrographs using synthetic rainfall data showed that effective precipitation volumes were less for after-treatment conditions than for before-treatment conditions. Hydrograph peaks occurred earlier for all storms after treatment, but peak rates varied depending on storm pattern. Direct treatment effects were obscured by the in-

creased drainage area after treatment (secs. 5.2.1 and 5.2.1.1).

Annual evapotranspiration for individual years ranged from 29.86 inches on watershed W–2 to 40.66 inches, also on watershed W–2. The 15-year averages were 35.97 and 35.08 inches for W–3 and W–2. The 5-year average at W–2 increased about 4 inches after treatment. The 5-year average at W–3 after treatment was about 2 inches more than the 5-year average before treatment. The averages were all considerably less than the 42.41-inch value reported for the Kissimmee River Basin (sec. 5.4.1).

The average annual rainfall was 48.84 inches for watershed W–2 and 47.68 inches for subwatershed W–3 over the 15-year period of record. The 5-year average after treatment was 2.63 inches greater than the 5-year average before treatment. Over the same two periods, average rainfall for subwatershed W–3 was 2.12 inches greater after treatment than before treatment (sec. 5.4.1). Differences in rainfall as well as changing land use (sec. 1.2.5) probably affected the annual evapotranspiration and annual water yields before and after treatment as much as the channelization treatment.

Nitrate-nitrogen unit contributions were greatest from the dairy-intensive area in Upper Taylor Creek watershed when compared with beef-cattle pasture or a combination of beef-cattle pasture and citrus groves. Annual nitrate-nitrogen loads from the 104-square-mile area ranged from 6.54 to 22.49 tons for 3 years (sec. 5.5.2.1).

Orthophosphate-phosphorus unit loads were greatest from dairy-intensive drainage areas, followed by beef-cattle pasture areas, with the combined beef-cattle pasture and citrus area producing the lowest unit load. Discharge of orthophosphate apparently resulted from a flushing action. The 3-year maximum load from watershed W–2 was 79 tons (sec. 5.5.2.2).

Chloride discharge data show that the greatest concentrations and loads occurred in citrus-producing areas, where irrigation from artesian wells is significant. A chloride load of 25 tons per square mile for a 3-month period was observed for 35-square-mile watershed W–5 (sec. 5.5.3).

1.—Introduction

A memorandum of understanding was executed in 1955 for cooperative hydrologic research among the Agricultural Research Service (ARS), the Central and Southern Florida Flood Control District (CSFFCD),[1] and the University of Florida Agricultural Experiment Station (FAES). The memorandum specified partial funding support of the research by the CSFFCD. The memorandum also provided that the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers give informal advice and assistance in planning investigations, water-control works, and land-use developments. Cooperative research between ARS and the Soil Conservation Service (SCS) was continued, without a formal memorandum of understanding, from prior agreements of 1954 when the SCS Research Division became, organizationally, a part of ARS.

Upper Taylor Creek watershed, located in Okeechobee County, Fla., was selected for hydrologic studies in 1955 because (1) it was a part of the overall area contained within the CSFFCD project,[2] (2) there was a need by SCS and CSFFCD for hydrologic data from natural watersheds in central Florida, and (3) a request was received by SCS for improvement works to facilitate drainage and maintain water-level control under the Watershed Protection and Flood Prevention Act (Public Law 566, 83d Congress, 68 Stat. 666, as amended).

The original Taylor Creek watershed consisted of 89,500 acres (139.8 square miles). The study area, designated Upper Taylor Creek watershed, originally consisted of 63,170 acres (98.7 square miles) above Okeechobee, Fla. During the study period, additional ditching in the headwaters areas increased the drainage area to 66,880 acres (104.5 square miles), effective January 1, 1967.

A watershed work plan was developed for the Taylor Creek watershed in 1959 by the Okeechobee Soil Conservation District and Okeechobee City Council, which were assisted by SCS. Floodwater damage to crops and pastures was identified as the major problem. Additional problems included inundation and damage of highways and damage to fish and wildlife habitats resulting from wide fluctuations of alternate flood and drought conditions. Pasture damages were found to include loss of stands, reduction of grazing time, and the reversion of improved pastures to a less productive state. Damages were related to inundation. Major floods occurred when the soil profile was saturated and additional high-intensity rain or sustained rainfall produced almost 100 percent runoff. The capacity of the existing channels was insufficient for the volume of runoff, and a sheet of water covered much of the flat watershed, with inundation continuing for periods up to 40 days. Major floods occurred at a frequency of once in 4 years. On-farm drainage ditches and canals lowered the water table excessively during dry seasons. (Rainfall during 5 to 7 months of the year is generally deficient for good crop and pasture yields.) Water-level control was needed to prevent overdrainage.

Recommended improvements under the work plan (as amended) to alleviate the watershed problems were as follows:

Land-treatment measures:

- Pasture planting.
- Irrigation pumping plants.
- Construction of 68 miles of open drains with water-control structures necessary for either drainage or seepage irrigation.
- Construction of 33 pipe-arch drop spillways where ditches enter improved channels (deleted from the plan in November 1962).

Structural measures:

- Channel improvement of 37.6 miles of stream channel.
- Construction of 13 single-purpose drop spillways for grade control.
- Construction of three Tainter-gate structures for water management.

Improvements under the work plan were accomplished in three phases over the period June 1962 to October 1968. Three of the water-management structures consisted of Tainter gates. Two of the structures, S–1 and S–2, had three 15-foot gates each, and S–3 had one 10-foot gate. Operation and maintenance of the Tainter gates were responsibilities of the Okeechobee County Road Department.

1.1.—Study Plan

The memorandum of understanding in 1955 provided for watershed engineering investigations in the Southern Florida Flatwoods. The upper portion of the Taylor Creek

[1]Now the South Florida Water Management District.

[2]The CSFFCD project was authorized by the Congress and described in House Document 643, 80th Congress, as amended.

watershed was selected for the investigations. The responsibility of ARS in the investigations was assigned to its Soil and Water Conservation Division's field location at Fort Lauderdale, Fla. The research later came under the Southeast Watershed Research Center, Athens, Ga., now designated the Southeast Watershed Research Program (SEWRP), Tifton, Ga., and was shared with ARS's Soil and Water Research Unit at Gainesville and Ft. Pierce, Fla.

The general objectives of the investigation were to determine rainfall-runoff-evapotranspiration relationships for natural watersheds and to determine the effects of channel improvement and associated water-control structures on storm runoff, water yield, and ground water.

1.1.1.—General Purpose

The general objectives of the Upper Taylor Creek watershed study were agreed upon among ARS, CSFFCD, FAES, and SCS. The objectives were not formally documented in the memorandum of understanding but were included in ARS research outlines. The specific objectives were (1) to determine the precipitation characteristics influencing runoff; (2) to determine the characteristics of runoff; (3) to establish the desired relationships among rainfall, ground water, and runoff for natural streams; (4) to determine the effects of channel improvements and associated water-level controls on storm runoff, water yield, and ground-water levels; (5) to determine evapotranspiration from agricultural watersheds; and (6) to relate the climatic factors with consumptive use and water yields on a watershed basis.

During the latter years of the study, environmental concerns, especially with respect to Lake Okeechobee, resulted in a water-quality survey to identify the sources of various pollutants of streamflow in the Upper Taylor Creek watershed.

1.1.2.—Procedures

General procedures included (1) collection, assemblage, and reporting of pertinent data; (2) analyses of such data to develop procedures for evaluating watershed treatment effects; (3) development of procedures for describing rainfall, streamflow, ground-water, and evapotranspiration characteristics; and (4) comparison of methods and procedures with results from other watershed studies to develop regional techniques.

1.1.3.—Cooperators' Responsibilities

The responsibilities of SCS were (1) to assist the local sponsors in developing and installing a program of watershed protection and flood prevention, and (2) to determine watershed physical characteristics by surveys and by inventory of watershed land use.

The responsibilities of FAES were (1) to assist in planning instrumentation, (2) to provide facilities as required, (3) to make analytical measurements on water samples as needed, (4) to assist in determining the soil physical properties, and (5) to assist through consultation as needed.

The responsibilities of CSFFCD were (1) to assist in planning instrumentation, (2) to indirectly provide streamflow data through reimbursement of USGS, and (3) to furnish funding assistance to ARS.

The responsibilities of ARS were (1) to assist in planning instrumentation; (2) to install, operate, and maintain mutually selected instrumentation; (3) to assist in assembling and processing basic data, as mutually agreed upon; (4) to make data available to CSFFCD and SCS as required; (5) to analyze, evaluate, and interpret data and results; and (6) to prepare and publish a comprehensive report of the project.

1.1.4.—Data-Collection Responsibilities

ARS collected precipitation data from a network of recording precipitation gages. From 1955 to 1961, ARS maintained six recording gages, and a local resident under contract with ARS maintained a U.S. Weather Bureau (USWB) standard gage. In 1961, the standard gage was replaced with a recording gage, also operated by ARS. Gages for the total watershed area (W–2) and each of the subwatersheds (W–3 and W–5) are listed in table 1.1. Also shown are Thiessen weights for all gages in the three areas for applicable time periods.

Under contract with the CSFFCD, the USGS collected streamflow data at two sites from 1955 to 1964. In 1964, a third site was added. For purposes of referencing to Water Resources Data publications, the USGS identifications were: watershed W–2—Taylor Creek above

Table 1.1.—Thiessen-weighted precipitation, by percentage, for Upper Taylor Creek watershed

Watershed and effective period of record		Rain gage 1	2	3	4	5	6	7
W-3	Beginning of record to Dec. 31, 1966	43	57					
	Jan. 1, 1967, to present	55	39	6				
W-5	Beginning of record to Dec. 31, 1975						36	64
	Jan. 1, 1976, to present				3		31	66
W-2	Beginning of record to Dec. 31, 1966	9	13	10	15	12	18	23
	Jan. 1, 1967, to present	12	12	11	15	11	17	22

Table 1.2.—Drainage areas and discharge conversion factors for gaging sites on Upper Taylor Creek watershed

Watershed	Area (mi^2)	Effective period of record	To convert mean daily discharge in ft^3/s to in/d, multiply by—
W-3	15.7	Beginning of record to Dec. 31, 1966	0.00236879
	19.1	Jan. 1, 1967, to present	.00194712
W-5	35.4	Beginning of record to Dec. 31, 1975	.00105056
	32.8	Jan. 1, 1976, to present	.00113384
W-2	98.7	Beginning of record to Dec. 31, 1966	.00037680
	104.5	Jan. 1, 1967, to present	.00035589

Okeechobee, watershed W-3—Taylor Creek near Basinger, and watershed W-5—Williamson Ditch at S-7 near Okeechobee. The three gaging sites and their drainage areas are shown in table 1.2. As discussed in a later section, drainage areas changed because of increased channelization and drainage patterns. Both original and revised areas are given in table 1.2.

ARS collected ground-water-elevation measurements from seven observation wells equipped with analog stage recorders. Ground-water-level measurements were collected by ARS at two well lines near the mainstream channel; each line consisted of seven wells. Manual measurements were made weekly at six wells in each line. The remaining well was equipped with an analog stage recorder.

A local resident, under contract with ARS, made measurements of daily maximum and minimum air temperature and daily pan evaporation from a USWB evaporation pan.

SCS prepared soils maps and made periodic inventories of land use and treatment. In 1972, ARS implemented a water-quality survey at 15 selected ground-water and streamflow locations. Samples were collected at approximately biweekly intervals. In 1974-75, samples were collected at 11 streamflow locations at approximately 1-week intervals. ARS and FAES made measurements of pH, chloride, nitrate-nitrogen, orthophosphate-phosphorus, iron, turbidity, and conductivity. Three-inch undistrubed soil cores at continuous 3-inch increments, to a total depth of 3 feet, were obtained at ground-water observation well sites. ARS and FAES made hydraulic conductivity measurements and determined moisture retention and release characteristics for each sample.

1.2.—Watershed

1.2.1.—Location

The Taylor Creek watershed is located in the Southern Florida Flatwoods land resource area of the Coastal Plain physiographic province (*13, 20*)[3] (fig. 1.1). Of the 89,500 acres (139.8 square miles) of total watershed area, only about 63,170 acres (98.7 square miles), designated as Upper Taylor Creek watershed W-2, were included in the study. Taylor Creek originates at about the center of Okeechobee County (fig. 1.2). It flows in a southeasterly direction, with the natural channel passing through the town of Okeechobee, and drains into Lake Okeechobee at hurricane gate No. 6. After June 1973, Upper Taylor Creek flow was diverted through canal L-63N to the Nubbin Slough inlet to Lake Okeechobee.

Upper Taylor Creek watershed was a predominantly agricultural and wooded area during the period of this study. The terminal gaging station was at Cemetery Road bridge (NW¼ sec. 3, T. 37 S., R. 35 E.) about 0.8 mile (1.3 kilometers) downstream from the crossing of U.S. Highway 441 and about 2.8 miles (4.5 kilometers) north of Okeechobee (fig. 1.3). The gaging stations were maintained on the main stream at structure S-3 (SE¼ sec. 26, T. 35 S., R. 34 E.) on State Highway 68, about 8.5 miles (13.7 kilometers) east of Basinger, and at structure S-7 on Williamson Ditch tributary (NW¼ sec. 34, T. 36 S., R. 35 E.) 450 feet (135 meters) from confluence with Taylor Creek and 3.6 miles (5.8 kilometers) north of Okeechobee. From 1964 to 1973, an auxiliary stage gage was maintained at structure S-1 on the main stem (NE¼

[3]Italic numbers in parentheses refer to items in "Literature Cited," p.114 .

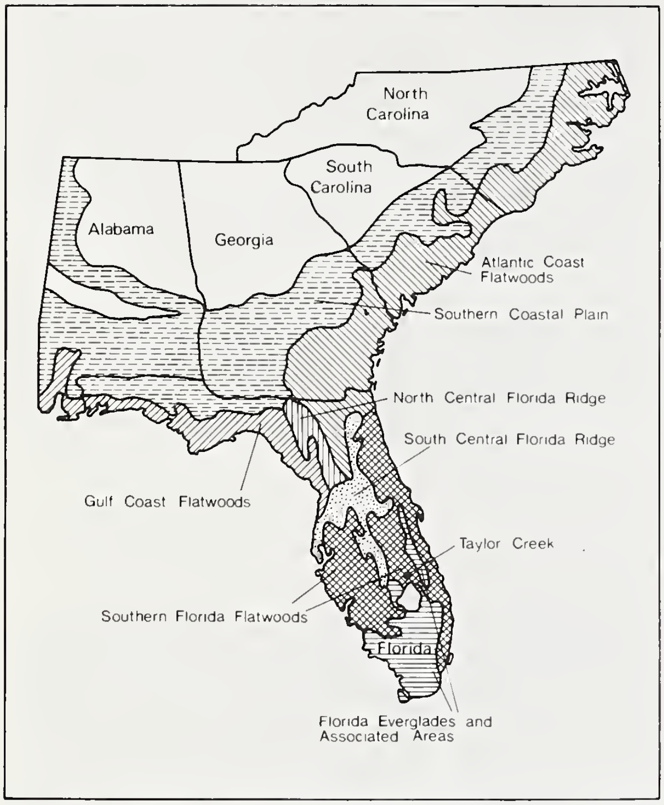

FIGURE 1.1.—Major land resource areas of the Southeast.

FIGURE 1.2.—Location of Taylor Creek watershed in south Florida.

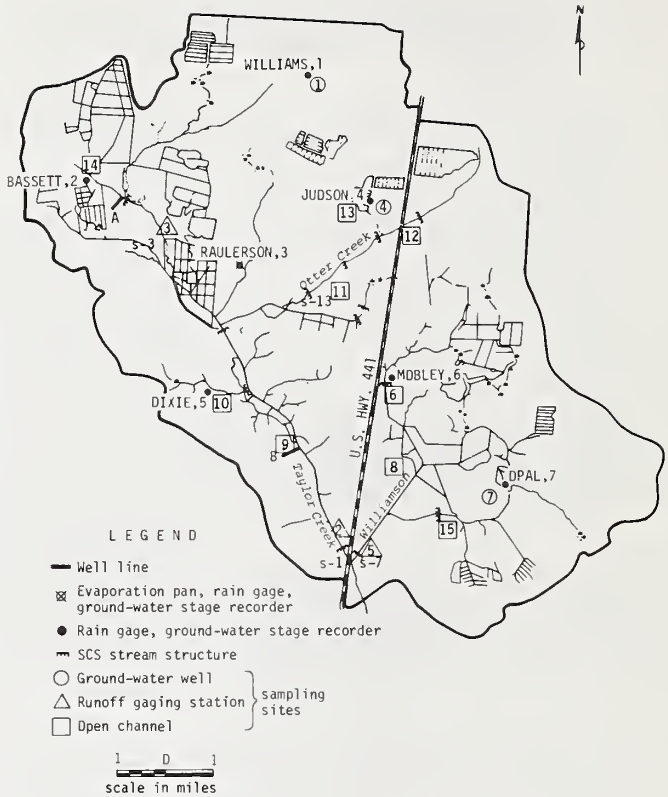

FIGURE 1.3.—Upper Taylor Creek watershed W-2. (Revised watershed boundaries beginning January 1, 1967.)

sec. 33, T. 36 S., R. 35 E.) 800 feet (240 meters) upstream from U.S. Highway 441.

Drainage areas of two subwatersheds (fig. 1.4) were 10,050 acres (15.7 square miles) for W-3 and 22,660 acres (35.4 square miles) for W-5. Seven precipitation gages and ground-water observation wells were established in 1955 and 1959, respectively.

1.2.2.—Geology and Soils[4]

Undifferentiated marine terrace sands of Pleistocene age are found as surface deposits (*34*). Generally, the sands are white to gray in the upper horizons and grade into tan, orange, and red in the lower horizons. They are the sub-rounded-to-sharp, nonfrosted detrital sediments that are characteristic of marine deposits. In the field it is impossible to distinguish between these terrace sands except by their altitudes.

[4]From Speir et al. (*46*) and McCollum and Pendleton (*30*).

The strand line of the Penholoway Terrace is about 68 feet above mean sea level (m.s.l.), and that of the Talbot-Terrace is about 45 feet above m.s.l. The Penholoway Terrace which covers approximately 40 percent of the area, lies in the northeastern part of the watershed. It forms a broad, flat, little-dissected plain that slopes gently to the south, where it is broken by the wave-cut scarf of the lower Talbot surface. Approximately 15 percent of the watershed consists of a sloping scarf area between the Panholoway and Talbot plateaus. The Talbot Terrace occupies the remaining 45 percent of the watershed area. It is remarkably flat; drainage is sluggish; and sloughs, shallow ponds, and swamps are abundant. The outer limit of the Talbot Terrace is generally ill-defined by the 22-foot strand line of the old Pamlico sea along the lower section of Taylor Creek.

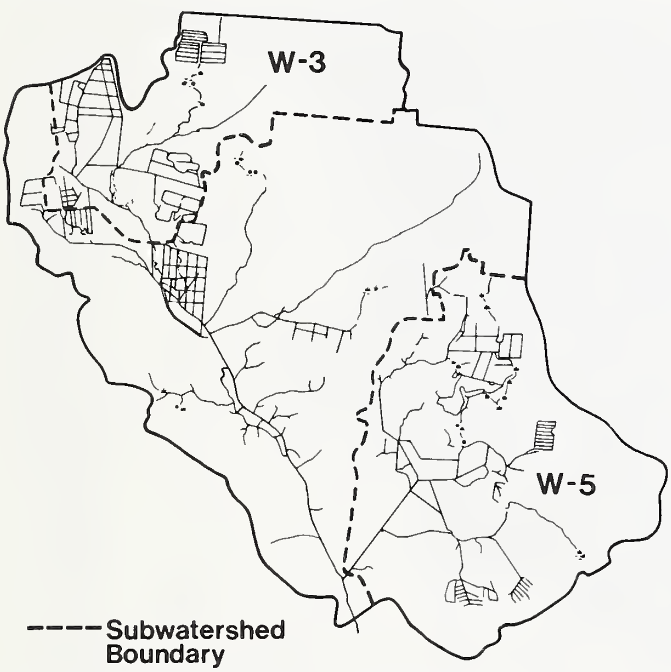

FIGURE 1.4.—Upper Taylor Creek watershed W-2, showing subwatersheds W-3 and W-5. (Revised watershed boundaries beginning January 1, 1967.)

The upper Taylor Creek basin is underlain by the Floridan aquifer. The impermeable Hawthorne Formation, which apparently underlies the entire peninsula except the Ocala uplift, forms an aquiclude that seals off the artesian water in the Floridan aquifer. The Hawthorne Formation also serves as a "floor" for generally unconfined ground water in the Caloosahatchee Formation (Pliocene) and in the mantle of sandy Pleistocene sediments.

The piezometric head of water in the Floridan aquifer beneath W-2 is approximately 50 feet above m.s.l. Since about one-half of the land lies above this elevation, flowing artesian wells can be obtained only in the lower elevations in the southern part of the watershed. A few such wells are used for irrigation. Limited supplies of ground water for local use can be obtained from the more permeable strata of the Caloosahatchee or the Pleistocene sediments. The ground-water level in the watershed is generally within 1.5 to 3 feet of the surface and shows marked response to local weather conditions.

Soils of Upper Taylor Creek watershed are generally fine grain sands formed in material of marine origin, with moderate to very rapid permeability and slow to very rapid internal drainage. Myakka-Basinger fine sand is the major soil association (table 1.3 and fig. 1.5). Soils data, surface slope, erosion class, and land capability are given for W-2 and W-3 in tables A-1 and A-2 (*20, 30*) of the appendix.

Table 1.3.—Percentage of each soil association in watershed W-2 and subwatersheds W-3 and W-5

Map symbol	Soil association	W-2	W-3	W-5
1	Pomello-Paola	<1	0	0
2	Myakka-Basinger	70	85	65
4	Parkwood-Bradenton-Wabasso	10	6	10
5	Placid-Pamlico-Delray	<1	0	0
6	Pompano-Charlotte-Delray-Immokalee	5	9	6
7	Manatee-Delray-Okeelanta	9	0	10
10	Okeelanta-Delray-Pompano	6	0	9

1.2.3.—Fluvial Geomorphology[5]

1.2.3.1.—Physiographic Setting

Taylor Creek is located in the East Florida Flatwoods physiographic subprovince (*13*). Drainage is to the south into Lake Okeechobee, then into the Gulf of Mexico through the Caloosahatchee River or into the Atlantic Ocean through the St. Lucie Canal or other canal systems.

1.2.3.2.—Geomorphic Interpretations

Data were taken from the USGS 7.5-minute quadrangle sheets. This limits the extent of the investigations, since not all stream channels appear on the maps, and the 5-foot contour increments do not allow the resolution desired for detailed topographic definition. Assuming,

[5]From Speir et al. (*46*).

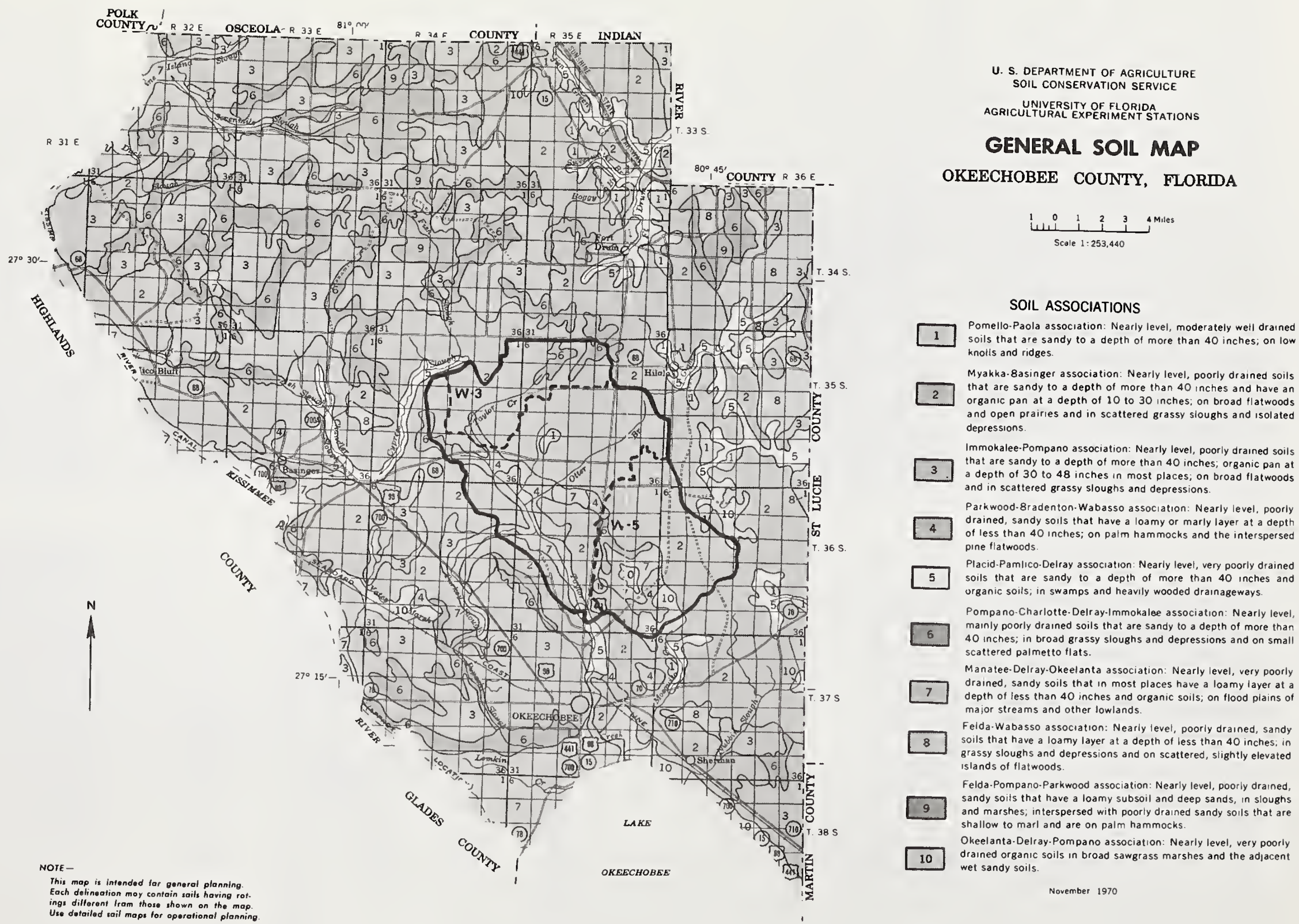

FIGURE 1.5.—General soil map of Okeechobee County, Fla., showing soil associations in Taylor Creek watershed. (Revised watershed boundaries beginning January 1, 1967.)

however, that little better information can be obtained for any other area in this region, these maps suffice to describe basic geomorphic features.

A method similar to that of Strahler (*50*) was used to compute the drainage density of Taylor Creek. First-order channels are unbranched tributaries at the head of the drainage net. Second-order channels are formed when two first-order channels converge, and so on. First-order channels can enter any higher order channel along its length as long as the first-order channel is unbranched. The highest order channel is, therefore, the one through which the water leaves the watershed. Table 1.4 gives the drainage net characteristics of Taylor Creek as computed from the 7.5-minute quadrangle sheets.

Drainage density (D_d) is the total length of the channels in miles divided by the area in square miles (*50*). In W–3 the 0.72 value is low, perhaps because the upper watershed is developed almost entirely on the Penholoway Terrace. According to geomorphic theory, the low density of the channel network indicates that little of the runoff occurs as overland flow. When the entire watershed (W–2) is considered, the D_d is higher, indicating that infiltration capacity is lower on the Talbot Terrace than it is in the upper portions of the catchment area.

The bifurcation ratio (R_b) is quite low on both the upper and lower portions of the watershed. This parameter, which is a measure of the ratio between successive stream order segments (*23*), indicates that the length of the watershed is not disproportionately greater than the width. Therefore, few first-order channels enter the higher order channels, a phenomenon explained by the low D_d. However, when the entire watershed is considered, the R_b value is about 50 percent greater. Thus, R_b is related to the size of the watershed.

Stream frequency (F_s), which is a measure of the total number of stream order segments over the area in square miles, is also low (*50*). Probably few other areas of the State or Nation, except the Coastal Terraces, exhibit such low stream frequencies. The stream length ratio (R_L) is defined as the ratio of mean length of segments of one order to mean length of segments of the next lower order (*29*).

Certain parts of the watershed have intensive field ditches established for drainage or seepage irrigation of pastures or for short-term vegetable crop production. These systems were not included in the above analysis (*46*).

The hypsometric curves for W–2 and W–3 are shown in figures 1.6 and 1.7. In these two graphs, relative height (h/H) is plotted against relative area (a/A), where y equals the ratio of height of a given contour increment (h) to total basin relief (H) and x equals the ratio of horizontal cross-sectional area (a) to the entire basin area (A), as defined by Langbein and others (*29*).

The curve in figure 1.6 clearly shows the portion of W–3 that lies on the upper (Penholoway) terrace. The flat up-

Table 1.4.—Stream geomorphic characteristics of watershed W–2 and subwatershed W–3

Watershed	Original area (mi²)	Channel order No.[1]	No. of channel segments (ΣN)	Bifurcation ratio[2] (R_b)	Length of channel[3] (mi) (ΣL)	Length of channel[3] (mi) (av. L)	Length ratio[4] (R_L)	Drainage density (D_d)	Stream frequency (F_s)	Length of overland flow[5] (L_q)
W-3	15.7	1	5		6.43	1.29		0.72	0.51	0.69
				2.50			1.43			
		2	2		3.71	1.85				
				2.00			.66			
		3	1		1.22	1.22				
W-2	98.7	1	85		61.9	72		1.20	1.19	.45
				4 25			1.82			
		2	20		26.3	1.31				
				2.22			1.33			
		3	9		15.7	1.74				
				4.50			3.48			
		4	2		12.1	6.05				
				2.00			.33			
		5	1		2.0	2.00				

[1]As defined by Strahler (*50*).
[2]For the 8 segments of W–3, R_b=2.25; for the 117 segments of W–2, R_b=3.24.
[3]For the 8 segments of W–3, ΣL=11.36; for the 117 segments of W–2, ΣL=118.0.
[4]For the 8 segments of W–3, R_L=1.04; for the 117 segments of W–2, R_L=1.74.
[5]L_q is average distance between drainageways.

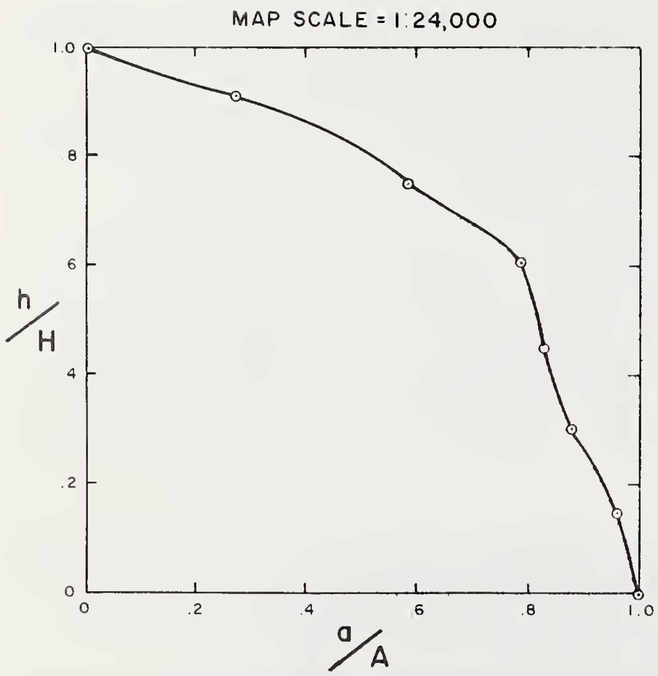

FIGURE 1.6.—Hypsometric curve, subwatershed W-3. (*h/H*, relative height; *a/A*, relative area.)

per part, which represents 78 percent of the total area, is entirely on the Penholoway surface. The remaining portion of the curve (22 percent) represents the area of relatively strong relief (the break between the two terrace levels) and a small portion of the Talbot Terrace just upstream from the gaging site in W-3.

Figure 1.7 gives a composite picture of watershed W-2. Both terraces are prominently represented, and the curve shows the percentage of area that each occupies on the watershed. Ground-water levels were measured at seven wells randomly located on the watershed. By taking the mean-annual depth of the water table below the surface and extrapolating the contour map for the top of this surface, a hypsometric curve was drawn. The results, as shown in figure 1.8, are almost congruent to those in figure 1.7. Therefore, there is little difference between the ground surface and the surface of the water table, which lies from 1 to 3 feet below ground level.

Although the longitudinal profile of the main channel does not show the two terraces as well as the hypsometric plotting does, it indicates the areas where channel stabilization would be most needed on this watershed in its natural state. Since the Talbot Terrace was abandoned by the sea, the channel has adjusted and degraded itself upstream to

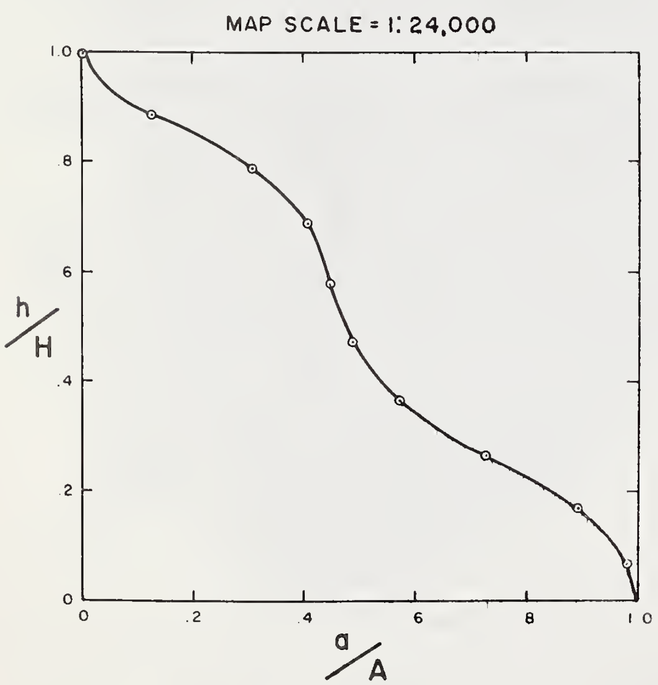

FIGURE 1.7.—Hypsometric curve, watershed W-2. (*h/H*, relative height; *a/A*, relative area.)

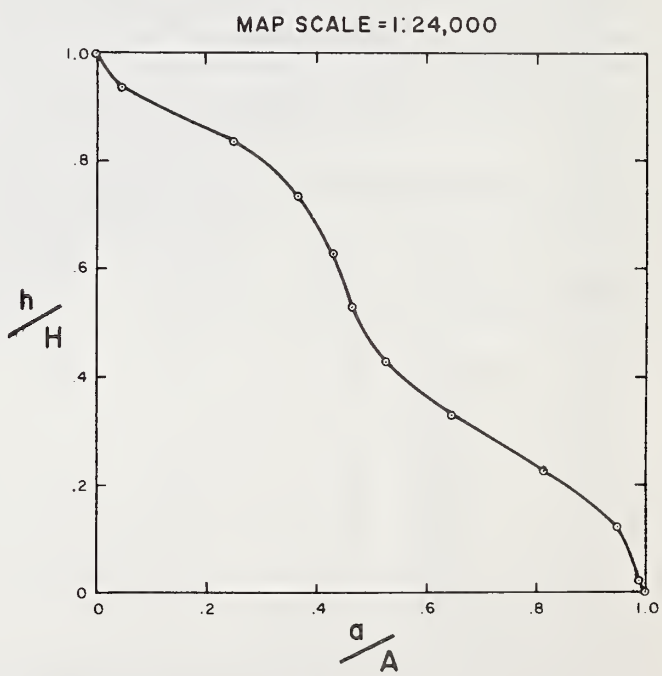

FIGURE 1.8.—Water-table hypsometric curve, watershed W-2. (*h/H*, relative height; *a/A*, relative area.)

compensate for the 30-foot drop between the two terraces. Through natural processes, the channel should tend to smooth out completely. Because this has not yet happened, it can be expected to be the more geologic change in the future. A drop structure near the outlet of W–3 was located in a reach of the channel where the gradient is greater than at any other location along the main stem (fig. 1.9).

1.2.4.—Topography and Surface Drainage

The topography of Upper Taylor Creek watershed is shown in figure 1.10 (original areas only; topographic survey not made on added areas). Elevations range from 25 feet above m.s.l. at the lower gaging station to 70 feet above m.s.l. at the upper watershed boundary. Land slopes are generally zero to 2 percent, but steeper slopes occur in a few minor areas. The watershed is relatively flat, with quasi-karstic topography (*46*). It contains

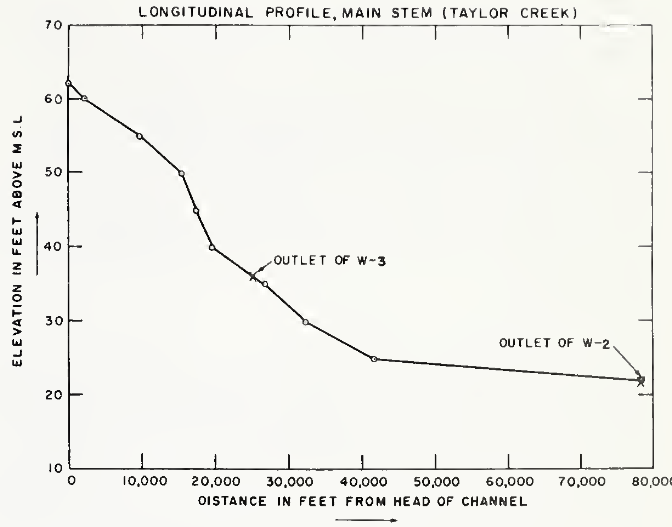

FIGURE 1.9.—Longitudinal profile of main stem, Taylor Creek.

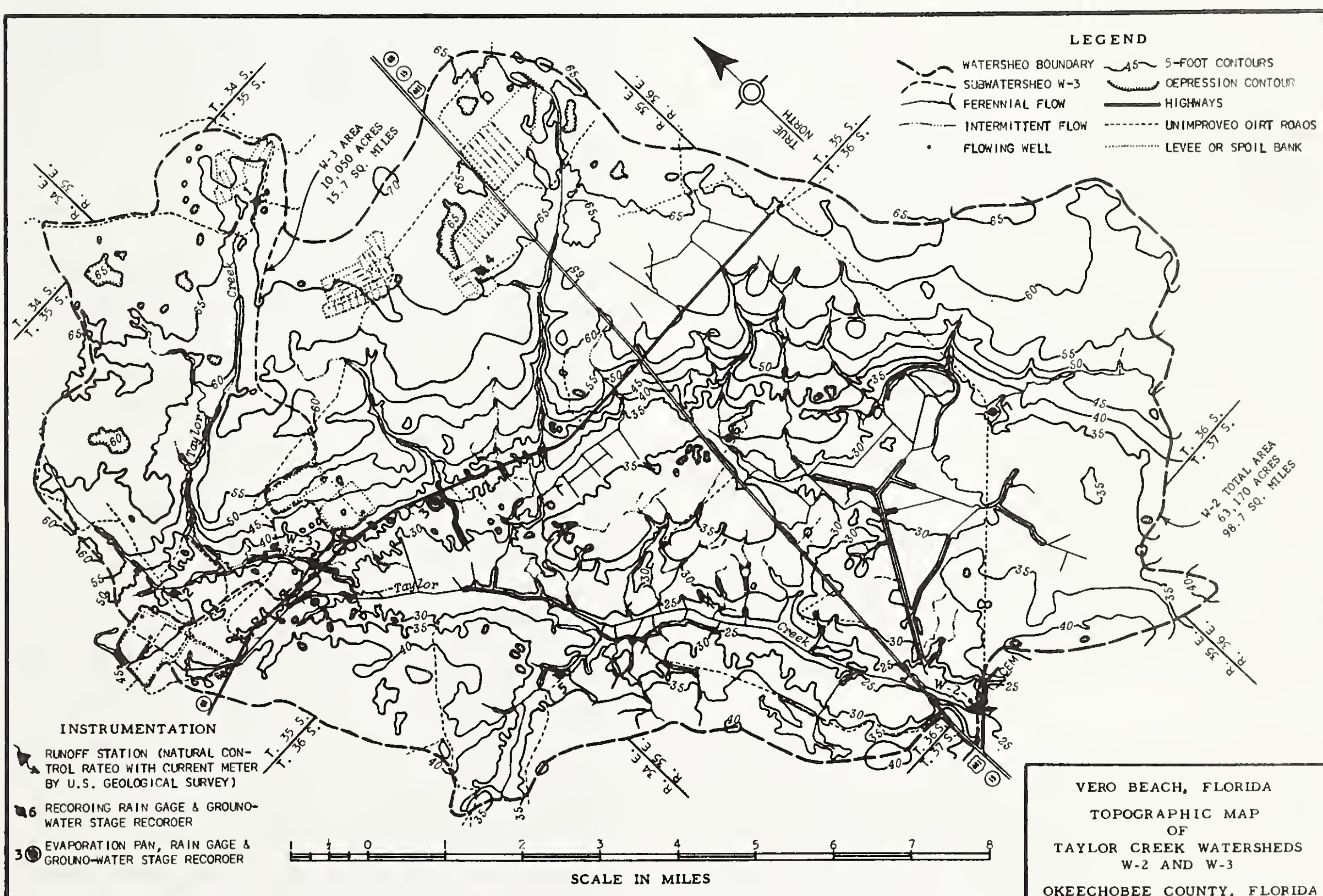

FIGURE 1.10.—Topographic map, Upper Taylor Creek watershed. (Watershed boundaries before January 1, 1967.)

numerous ponds and sloughs, and drainage ditches have been constructed for pasture improvement. The principal watercourse is 15.6 miles long, and it cuts through several Pleistocene marine terraces in the upper reaches, giving a "fall line" type of topography. The terraces in many cases form watershed boundaries. Surface drainage under natural conditions is sluggish, but storm drainage with improved channels is more rapid. Streamflow is mostly continuous from ground-water seepage following storm flows.

Extensive shallow field ditches (fig. 1.3) were dug throughout the watershed before development in 1959 of a work plan for Taylor Creek watershed under Public Law 566. Also, a large channel, Williamson Ditch, was constructed in about 1945 (fig. 1.3) to drain a large, shallow lake that was developed for beef pasture and some citrus (sec. 1.2.5). USGS 7.5-minute-series topographic maps and aerial photographs document the surface drainage feature in 1953 and 1972. Shallow-ditch systems increased considerably during this period.

1.2.5.—Land Use

The Upper Taylor Creek watershed is a predominantly agricultural and woodland area. Land use in the watershed continued to change during the period of observation, as evidenced by the SCS survey data given in table 1.5.

In 1959, the SCS work plan showed that about 1 percent of the watershed in cropland was devoted to citrus and winter vegetables. Citrus acreage increased only slightly through the duration of the study. Small acreages of tomatoes were developed in W–3. The common practice was to develop rangeland for tomato production for about 2 years. After the second year, the tomato-producing area was converted to improved pasture for beef production. New areas were then developed for tomatoes. The net results were a small increase of cropland acreage and an increase in improved pasture. The largest change in land use occurred in improved pasture. Considerable acreages of improved pasture were developed from unimproved rangeland.

The cattle industry in Upper Taylor Creek watershed was primarily beef cattle in 1959. Almost simultaneously with watershed improvement under the Public Law 566 program, urbanization in the Miami area forced the exodus of dairy farms. Several beef cattle ranches in the watershed were converted to dairy farms. Dairy farming in the watershed consisted primarily of large (about 1,000 milking head per barn), concentrated production units surrounded by improved pastures. Only small amounts of grain or high-protein crops were grown in the watershed, but feed concentrates were transported in from other areas. This practice resulted in a large influx of feed having high nitrogen and phosphorus content into the watershed.

Table 1.5.—Land-use results for watershed W–2 and subwatershed W–3

Land use	Percentage of watershed area used in — 1956	1960	1964	1968	1972
	WATERSHED W–2				
Cropland	1	1	1	2	4
Improved pasture	29	29	34	40	47
Range and forest	64	62	55	48	39
Miscellaneous[1]	6	8	10	10	10
	SUBWATERSHED W–3				
Cropland	0	0	0	0	1
Improved pasture	41	45	45	45	59
Range and forest	58	50	45	45	30
Miscellaneous[1]	1	5	10	10	10

[1]Roads, marsh, or urban use.

1.2.6.—Climate

The climate in the Taylor Creek vicinity is subtropical. Summers are long, warm, and humid with frequent showers that prevent temperatures from becoming extremely high. Winters are short and mild with little rainfall. Cold spells with frosts in the low-lying areas can be expected only a few times during winter. Advective freezes occur occasionally during winter. All the watersheds are within the area designated South and Central Division (Florida) by the USWB. The average annual temperature for south-central Florida is 72.7 °F. Maximum temperatures during the summer months average slightly above 90 °F, and minimum temperatures average 65 °F. Mean monthly minimum and mean monthly maximum temperatures are shown for Okeechobee hurricane gate 6 in figure 1.11. Average annual rainfall for the 44-year period at hurricane gate 6 on the northeast levee of Lake Okeechobee is 47.45 inches (*62*). Heaviest rainfall occurs in early summer. The distribution of average monthly rainfall at hurricane gate 6 is shown in figure 1.12. The south-central Florida area has extended periods of drought, although average annual rainfall is high. Years of deficient rainfall are common and appear to

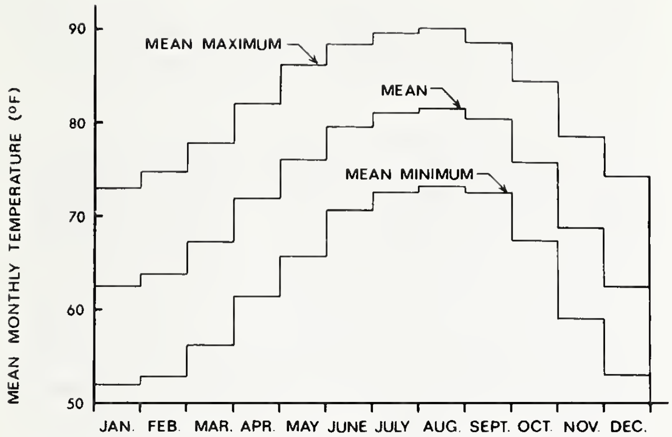

FIGURE 1.11.—Mean monthly temperatures, Okeechobee hurricane gate 6, 1919–71.

occur in sequence. Periods of drought are not necessarily restricted to the winter months.

March and April are the windiest months, and the prevailing winds are southeast and east. Because most winds pass over water surfaces, hot, drying winds are infrequent. High-velocity winds of short duration are associated with thunderstorms in summer and with cold fronts during other seasons. Tornadoes can occur anytime during the year but most frequently in spring, and they occasionally accompany tropical storms. Tropical hurricanes are the principal source of high winds and are usually accompanied by excessive rainfall.

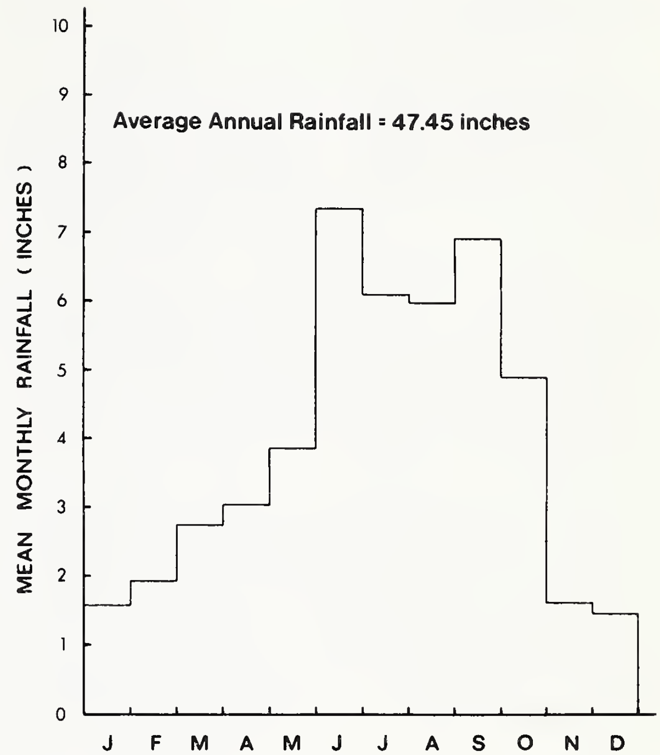

FIGURE 1.12.—Mean monthly rainfall, Okeechobee hurricane gate 6, 1919–71.

2.1.—Precipitation

Complete rainfall data are available for the USWB cooperative observer gage maintained by CSFFCD at Okeechobee hurricane gate 6 in Okeechobee. Monthly and annual summaries are given in table A–3 for the period of record, 1919–71 (*62*). Monthly maximum daily rainfall data for Okeechobee hurricane gate 6 are given in table A–4. In June 1955, ARS established a rain-gage network consisting of six weighing-recording gages equipped with weekly charts and one standard gage (fig. 1.3). Standard rain-gage 3 was maintained by Arthur Raulerson, under contract with ARS, as a part of the weather station. A recording gage was installed at No. 3 in October 1961.

Monthly and annual summaries of watershed rainfall, determined by the Thiessen method, are given in tables A–5, A–6, and A–7 for watersheds W–2, W–3, and W–5, respectively (*4–7, 20–22, 52*).[1] Hourly rainfall values were determined for each gage for the period of record. Monthly maximum 1-, 2-, 6-, 12-, and 24-hour rainfall values are given in table A–8 for rain gage 3. Monthly maximum daily rainfall data are given in table A–9.

2.2.—Streamflow

USGS established two streamflow gaging stations on Taylor Creek in June 1955. The uppermost station was designated "Taylor Creek near Basinger," where streamflow was measured from the W–3 subwatershed. The lower station, at Cemetery Road, was designated "Taylor Creek above Okeechobee," where streamflow was measured from the W–2 watershed. Both locations consisted of natural-channel measuring sections. A horizontal wooden control was constructed at W–3 for a better control section.

Water-management control structure S–1 was constructed in 1964 during SCS Phase I construction (table A–10) on Taylor Creek upstream from U.S. Highway 441. Structure S–1 consisted of a 50-foot-wide concrete structure with three 15-foot Tainter gates. USGS established an auxiliary gage at the location in June 1964, designated "Taylor Creek at S–1." ARS effected a contract with the Georgia Institute of Technology for scaled-model studies to develop stage-discharge relations for S–1 (*31*).

A 10-foot Tainter gate (S–3) was constructed during Phase II (table A–10) at the site of streamflow measurement for subwatershed W–3, and gate operation began in October 1964. Structure S–7 was also built in 1964 during Phase II on the Williamson Ditch tributary to Taylor Creek. The structure consisted of a 40-foot sharp-crest rectangular weir. A gaging station was established for subwatershed W–5 at S–7 by USGS and was designated "Williamson Ditch at S–7 near Okeechobee." Beginning in October 1964, USGS determined discharge at S–1 and S–7 and reported the total flow as streamflow for the W–2 watershed.

Authorization for operation of the Tainter gates within Upper Taylor Creek watershed was given to the Okeechobee County Road Department. Gate operation was totally subjective in that the gates had to be opened to pass floods and closed to maintain ground-water levels in the watersheds. At S–1 and other structures like it, the three Tainter gates were to be operated alike, that is, all three opened at the same time and the same amount and closed at the same time.

Following a meeting on January 16, 1968, of personnel from USGS, CSFFCD, ARS, SCS, and the Okeechobee Road Department, the following quotation from a letter[2] gave the requirements by USGS for operation of the Tainter gates at structures S–1 and S–3:

Structure 1

1. Gates should remain closed until a stage of 20.7 ft is reached (when gates are closed the top of gate elevation is 19.2 ft, thus a 1.5-ft head before opening the gates would be 20.7 ft).
2. Gates should be lowered or closed, so that the upstream stage does not fall lower than 17.5 ft.
3. The three gates should be operated in unison. Do not operate only one or two gates or set them on different settings.
4. Be especially sure that a log card of each gate change is properly filled out and mailed to USGS. If five gate changes are made in 1 day, then five cards must be filled out and mailed.

[1]Monthly and annual summaries reflect 0800 observational time for the period June 1955 through September 1961. After September 1961, the observational day ended at midnight. Summaries in this bulletin are consistent with previous publications. Analyses in this bulletin are based on midnight observational data.

[2]Correspondence from R. B. Stone, Jr., USGS, to W. H. Speir, ARS, dated January 17, 1968.

Structure 3

1. Gate should be either opened wide or closed. It is not necessary at this site to maintain a head.
2. Accurate logs of each gate change are most important here.

However, because of the inexperience of personnel in Tainter-gate operation, their lack of knowledge of hydrology and floods, and their difficulty in maintaining desired water levels, the gates were operated independently without good recordkeeping of times and amounts.

USGS published mean daily stage and discharge data for Taylor Creek near Basinger (W–3), Williamson Ditch at S–7 near Okeechobee (W–5), and Taylor Creek above Okeechobee (W–2) (*57–59*). Mean daily stage data only were published for Taylor Creek at S–1 (*58, 59*). During periods when the gates were open, USGS experienced difficulty in accurate determination of discharge and rated those records "poor."[3] Monthly and annual summaries of streamflow are given in tables A–11, A–12, and A–13 for watersheds W–2, W–3, and W–5, respectively. Annual maximum peak rates and volumes for selected time intervals are given in tables A–14, A–15, and A–16 for watersheds W–2, W–3, and W–5, respectively (*4–7, 20–22, 53*). Selected storm events have been published, including breakpoint rainfall and streamflow and watershed conditions (*4–7, 20–22, 54*). Monthly maximum mean daily discharge data are given in tables A–17, A–18, and A–19 for watersheds W–2, W–3, and W–5, respectively.

Following implementation of the channel improvement work, individual landowners constructed field drains and other drain works on their properties. Also, drain structures with flashboards were installed by landowners in some drainage ditches to provide field drainage and ground-water level control. Operation of flashboard controls and changing of field drainage may have changed the actual watershed boundaries from time to time. Therefore, drainage areas reported and used in determining unit-area streamflow may not always reflect the exact value. Analyses reported and interpreted in later sections may have some degree of bias as a result of inexact drainage-area delineation.

2.3.—Ground Water

In 1958–59, ARS installed ground-water observation wells at each of the seven rain-gage locations. Six-inch pipes were jetted in to a depth of about 7 feet. Continuous water-level recorders with weekly charts were installed at all wells. Measurements were made from ground surface to the phreatic water surface. Mean daily depths were determined for each location, and watershed averages were determined by arithmetic averaging for wells within each watershed. Mean monthly depths are given in tables A–20, A–21, and A–22 for watershed W–2 and subwatersheds W–3 and W–5, respectively.

Two lines of wells were installed in 1961 by ARS near the main channel of Taylor Creek. Each line consisted of seven wells; one was located at the stream and the others at distances of 10, 38, 70, 104, 535, and 2,000 feet from the stream. Two-inch pipes were jetted in for the wells. Locations of the two lines, designated "A" and "B", are shown in figure 1.3. Line A was about one-half of a mile upstream from the gaging station at structure S–3, and line B was about 1¼ miles upstream from structure S–1. Manual measurements were made at weekly intervals. In 1962, one location of an existing well on each line was selected as indicating "average" fluctuations, and the wells were modified by jetting in 6-inch pipes and installing continuous water-level recorders with weekly charts. The recorder well on line A was installed at the 70-foot location, and the recorder well on line B was installed at the 535-foot location. Because of the channel relocation during Phase II construction, the wells on line B at zero, 10, 38, and 104 feet from the channel were moved. Mean monthly depth to ground water is given in table A–23 for observation wells 1–7 and the recorder wells on lines A and B. Mean monthly ground-water elevations for the 104- and 535-foot well locations on line A and the 104-, 535-, and 2,000-foot locations on line B are given in table A–24.

2.4.—Temperature and Evaporation

Arthur Raulerson was also contracted by ARS to collect records of temperature and evaporation at the location of rain-gage 3. The measurements included daily maximum and minimum temperatures and daily pan evaporation. A USWB pan was installed for measurement of evaporation. Monthly and annual summaries of evaporation are given in table A–25. Temperatures were published for Okeechobee hurricane gate 6 for the period 1919–71 (*62*). Summaries of mean monthly temperatures are given in table A–26. Mean monthly maximum and minimum temperatures are given in table A–27.

[3]Personal communication with USGS personnel, April 1975.

3.—Precipitation Representativeness

2.5.—Water Quality

ARS established a water-quality survey in March 1972. Fifteen sampling locations were selected, as shown in figure 1.3. In addition to the three streamflow gaging stations, sampling locations included open-channel and ground-water sites with varying agricultural representation. Samples were taken manually at weekly intervals during the rainy season and biweekly during the dry season. Laboratory analyses were made to determine values of conductivity, pH, and turbidity and concentrations of orthophosphate-phosphorus, chloride, and nitrate-nitrogen; the results are summarized in table A–28.

3.1.—Annual Data for Record Period

Long-term precipitation data for Okeechobee hurricane gate 6 were analyzed to determine representativeness for the record period in Upper Taylor Creek watershed. The record at gate 6 was begun in January 1919 and was discontinued in November 1971, but several months of record are missing through 1929, as shown in table A–3. Therefore, analysis of annual data was made for 1930–70 as the total period and for 1956–70 as the record period.

A 1973 radar study showed that rainfall over Lake Okeechobee was about 1.5 percent less than rainfall over the surrounding land area (*37*). Although the ''lake effect'' was significant and undoubtedly had near-shore effects, using the data for Okeechobee hurricane gate 6 for long-term record was not serious. Since the gage location remained the same for the entire period of record, the lake effect should not have biased the short-term versus long-term comparison.

Annual precipitation amounts were organized into histograms and fitted with normal curves. Figures 3.1 and 3.2 show the histograms and statistics for the periods 1930–70 and 1956–70, respectively. The data closely approximate normal distributions for both periods. Also, there are few differences between the two periods in mean, standard deviation, skewness, and kurtosis; the 1956–70 period closely approximates the longer-term record.

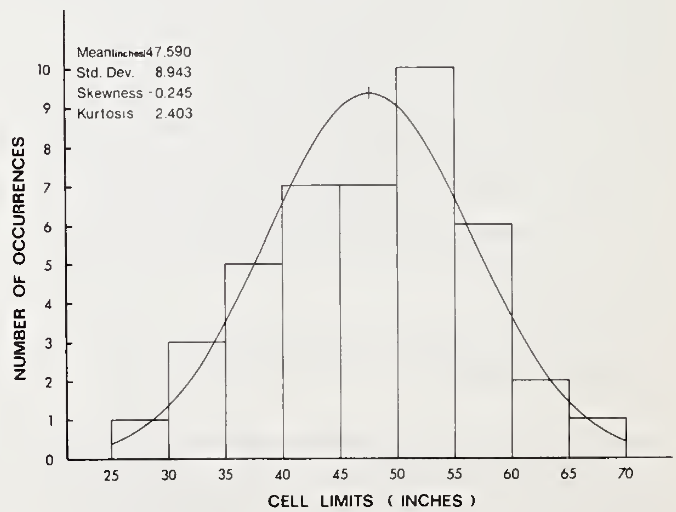

FIGURE 3.1.—Histogram of annual rainfall, Okeechobee hurricane gate 6, 1930–70.

The histograms for the long-term and record periods indicate a good range in annual amounts of rainfall in both "wet" and "dry" years. It is significant that the smallest and largest amounts of annual rainfall, 26.83 inches and 65.13 inches, occurred during the period 1956–70. These occurrences are probably contributing factors in the relative comparisons of the two periods. The average annual rainfalls for W-2 and W-3 were 48.82 inches and 47.99 inches, respectively, for the 1956 to 1975 period and for W-5 was 49.99 inches for the 1965–70 period (tables A-5—A-7). Based on these annual comparisons, the total record period in Taylor Creek can be considered representative of long-term precipitation.

3.2.—Monthly Data

Annual precipitation data do not describe distributions within the year. Rainfall distribution is important in the hydrologic response of a watershed. Monthly rainfall totals were analyzed to determine representativeness, thus providing some measure of distribution within the year. The long-term record (1919–71) for hurricane gate 6 was used in the monthly analysis.

3.2.1.—Record Period

Monthly rainfall amounts were compared for the 1919–71 and 1956–71 periods. Figure 3.3 shows a summary of maximum, minimum, and mean rainfall for each period during all months. These comparative values provide information about the respective ranges as well as some indication of the overall distribution. The long-term and record periods compare closely for the months of February, March, May, October, and December. Mean amounts for January, July, August, September, and November compare favorably, although monthly maximums differ considerably for both periods. Both monthly maximums and means are considerably different for April and June. Minimum values for June and September are drastically different for the long-term and record periods. Data for the months of June through October include some heavy tropical-storm rainfall. As indicated in section 1.2.6., the study area is subject to hurricanes during this season.

Since the individual monthly values reflect significant variability and since antecedent rainfall is significant in watershed response, moving averages were determined to compare the record period with the long-term period.

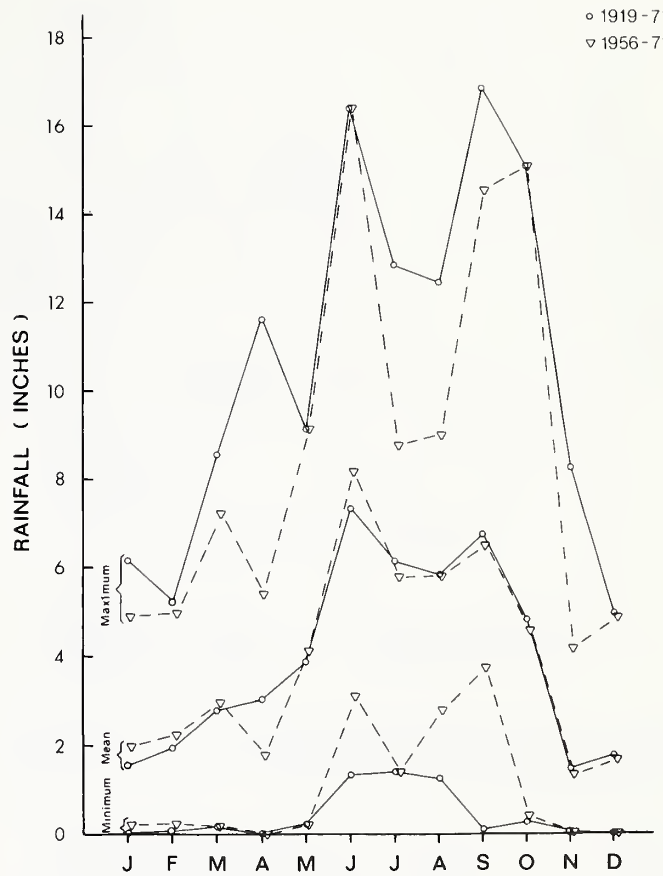

FIGURE 3.3.—Monthly maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

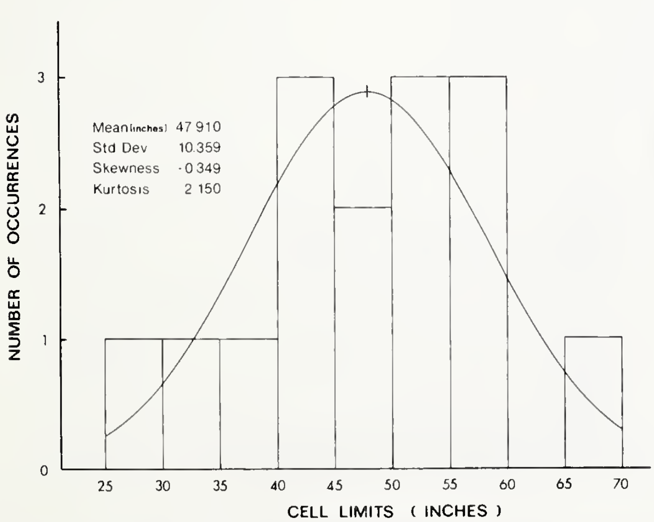

FIGURE 3.2.—Histogram of annual rainfall, Okeechobee hurricane gate 6, 1956–70.

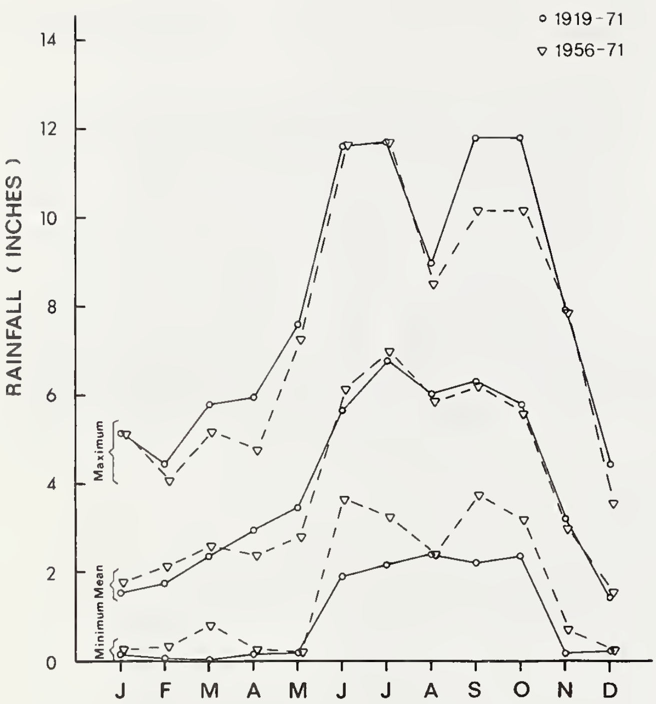

FIGURE 3.4.—Mean 2-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

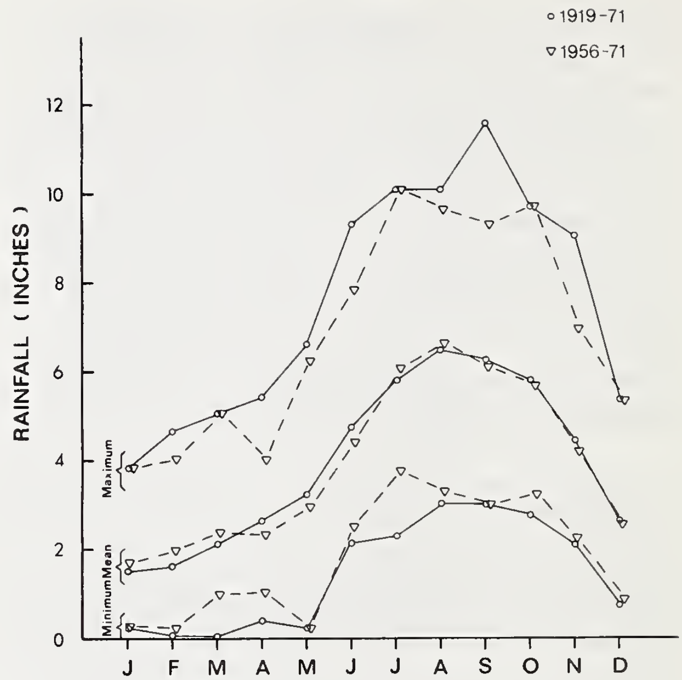

FIGURE 3.5.—Mean 3-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

Comparisons of maximum, minimum, and mean rainfall for 2-, 3-, 4-, 5-, and 6-month averages can be made from figures 3.4–3.8. This multimonth averaging process results in a smoothing effect that masks extreme values, i.e., the longer the averaging period, the more smoothing the effect on the annual values. However, the maximums, minimiums, and means compare quite well for most months. The greatest differences occur in the maximums during the rainy-season months of May through October. Multimonthly means are in good agreement. Again, the occasional tropical-storm caused the extreme maximum values. Averaging for the multimonth periods was not sufficient to override the tropical-storm effects. Based on the multimonth comparisons, precipitation for the period of record in Taylor Creek watershed is representative of the long-term normal.

3.2.2.—Treatment Periods

The record period in Upper Taylor Creek watershed, as previously stated in section 3.2.1., was 1956–71. This includes the before-channelization (before-treatment) period, channel-construction (treatment) period, and after-channelization (after-treatment) period. In order to accomplish one of the main objectives of the study, i.e.,

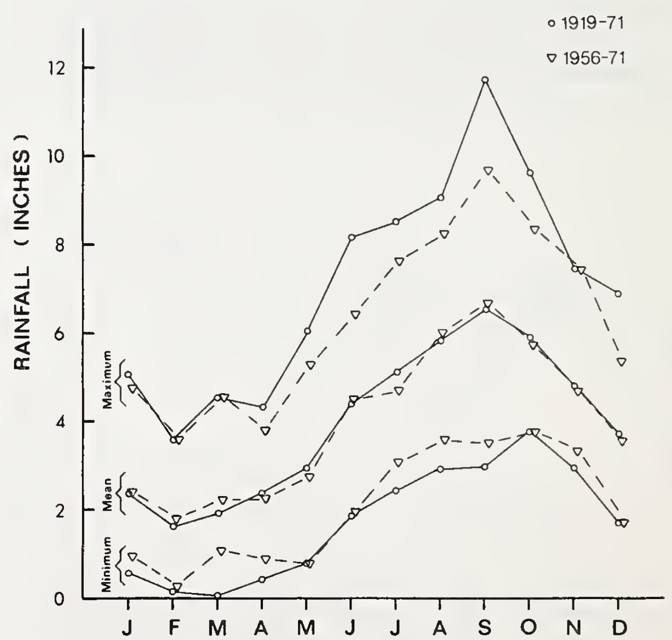

FIGURE 3.6.—Mean 4-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

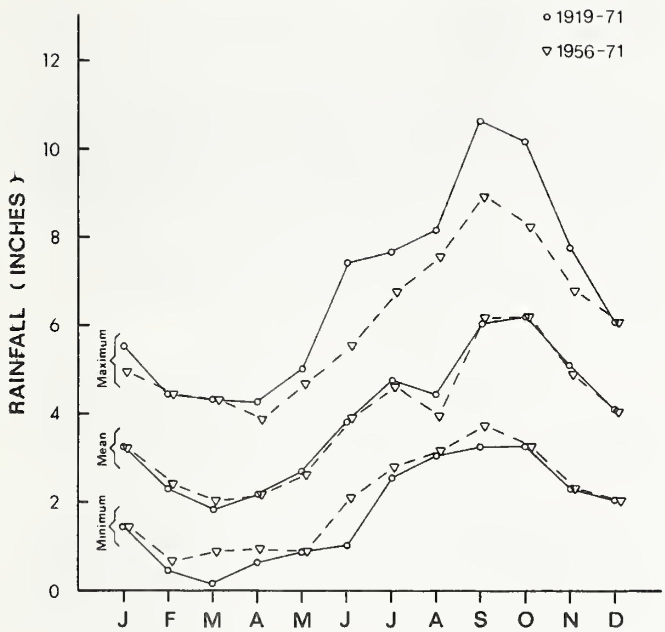

FIGURE 3.7.—Mean 5-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

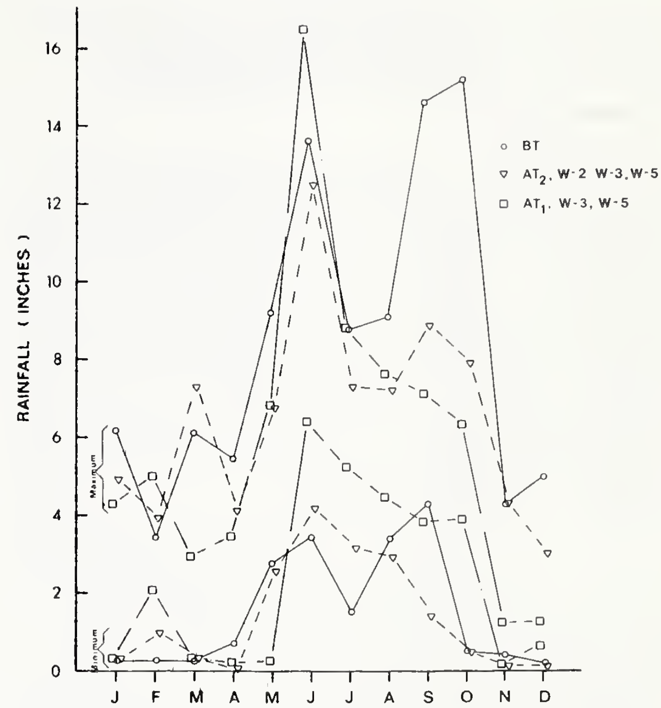

FIGURE 3.9.—Monthly rainfall, Okeechobee hurricane gate 6, 1955–72. Each symbol represents one measurement.

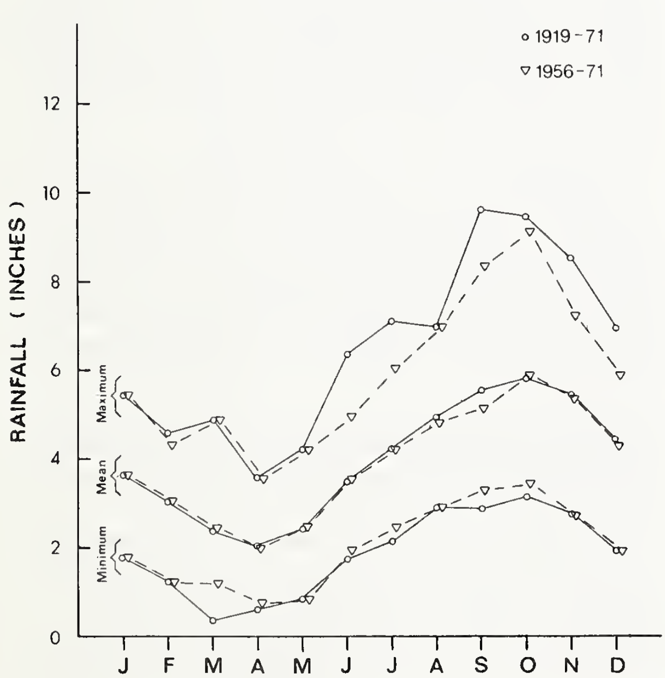

FIGURE 3.8.—Mean 6-month maximum, minimum, and mean rainfall, Okeechobee hurricane gate 6, 1919–71 and 1955–71.

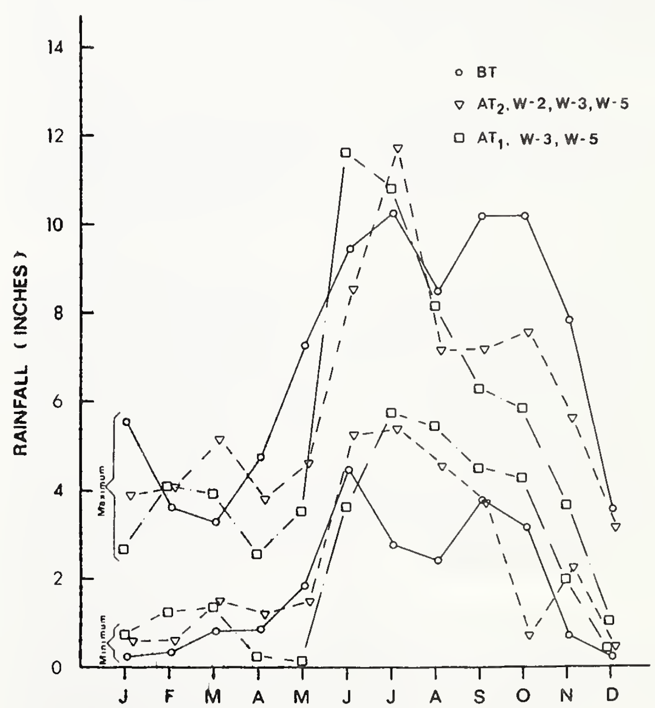

FIGURE 3.10.—Mean monthly 2-month rainfall, Okeechobee hurricane gate 6, 1955–72. Each symbol represents one measurement.

determine the effects of channelization on hydrologic response, it was necessary to further break the study period into segments and consider representativeness of precipitation.

The USWB location at Okeechobee hurricane gate 6 was discontinued in November 1971, but the Upper Taylor Creek watershed study was continued through 1972. In order to examine rainfall data for the before-treatment (BT) period and full after-treatment (AT) period, it was necessary to supplement the data from hurricane gate 6 with data from USWB location Okeechobee 9 SW. This location is about 10 miles from hurricane gate 6, but on a monthly basis, rainfall totals for the two locations are very comparable. This creates some bias but should be acceptable for the purpose intended.

All values of monthly rainfall were plotted in figure 3.9 for the BT and AT periods to allow a comparison of the data. Channelization and water-level control-structure construction were completed in subwatershed W–3 in 1964. However, treatment measures in watershed W–2 and subwatershed W–5 continued until June 1968. The AT period for W–3 was 1965–72 and for W–2 and W–5 was July 1968 through 1972. In figure 3.9, three periods are designated, i.e., BT (July 1955–December 1963), AT_1 (January 1965–June 1968), and AT_2 (July 1968–December 1972).

The range and distribution for the three periods compare quite well for most months. The largest monthly total on record occurred in June 1965, but the plotted point is not excessively out of line with the other data. The BT period showed more rainfall for January, April, May, August, September, October, and December. Averages for 2 months are shown in figure 3.10, in which the same trend is apparent for the same months. Based on the 1-month and 2-month data, the following summary of comparisons of rainfall for the periods was made: BT was greater than AT_1 and AT_2 for January, April, May, August, September, October, and November; AT_1 and AT_2 were greater than BT for March and July; AT_1 was greater than BT for June; and BT and AT were about equal for February and December.

We conclude that the BT period was wetter than the AT period, particularly during the rainy season (May through October). Based on this conclusion, comparison of hydrologic response of Upper Taylor Creek watershed for the two periods may well be biased. This fact must be kept in mind when drawing conclusions in the analyses sections.

4.1.—Precipitation

Precipitation characteristics treated in this section are analyzed strictly from the viewpoint of precipitation as an independent process. Consideration is not given to interrelations with or interpretations toward analyses of the streamflow and ground-water components of the study. Emphasis is placed on those characteristics that are significant in water-resources planning and design.

4.1.1.—Frequency of Daily Precipitation

Although maximum storm rainfall does not always result in maximum runoff and streamflow, extreme storm events generally result in large streamflow rates or volumes. Such extreme events are of particular interest in hydraulic and drainage design. A calendar day or 24-hour period is the customary time unit for rainfall in design and planning. Calendar days can be added conveniently to produce any desired time period.

The annual series is commonly used in most frequency analyses, but this results in disregarding large values during a single year that may be greater than the annual maximums for other years. An alternative that has been used is the partial-duration series, which considers all values above some arbitrary lower limit such that the total number of values equals the number of years of record (*60*). The partial-duration series results in a slight bias, and physical interpretation is not as exact.

Another alternative is to consider monthly maximums and determine the expected values of a variable for each month of the year. This can also create a bias if the data for each month are treated independently from every other month. Unless a planner is interested only in a particular month or season, this alternative will not produce the desired results.

Snyder (*39*) developed a procedure that makes maximum use of all data, unlike the annual series, but treats the monthly series as being continuous over the year. The method considers distribution parameters to be seasonally continuous and cyclic over a year. It was adapted to 12 monthly distributions simultaneously to treat monthly maximums over the year. The procedure was applied in hydrologic analyses of a North Carolina watershed (*55*).

The log-normal distribution approximates most hydrologic variables. Snyder and Wallace (*45*) developed the three-parameter log-normal distribution as a functional variate

transform of an embedded-normal distribution. The mean of the embedded normal and two parameters in the transform function were evaluated by nonlinear least squares. When so defined and evaluated, the three-parameter log-normal distribution is a good device for generating values of stochastic variables. The log-normal probability density function is given by

$$p(v)=[\sqrt{2\Pi}k(v-a)]^{-1}\exp\left\{-\tfrac{1}{2}\left[\frac{ln\ (v-a)}{k}-m\right]^2\right\}, \quad (4.1)$$

and the variate transform function is given by

$$ln\ (v-a)=kx. \quad (4.2)$$

In equations 4.1 and 4.2, x is the variate of the embedded-normal distribution of unit variance, m is the mean, v is the value of the variate, and a and k are mathematical parameters. Three parameters, a, k, and m, are evaluated by nonlinear least squares applied to historical data. Snyder's procedure considers parameters a and k to be seasonally continuous and cyclic over a year (*39*).

Monthly maximum daily rainfall amounts for Okeechobee hurricane gate 6 are given in table A-4 for 1930 through 1972. The nonlinear least squares method of fitting the log-normal distribution was applied to the monthly maximum rainfall data. Parameters a, k, and m were optimized by the method of least squares. Parameters a and k were optimized at three points during the year, with intermediate points determined by interpolation techniques (*42*). Histograms of observed data were developed using 0.50-inch class width. The 12 monthly distributions were fitted simultaneously, which resulted in the best fit of the total, not the best fit of any individual month. Observed and calculated histograms are shown in figure 4.1. Optimization of the parameters resulted in a correlation of 0.909 between observed and predicted values. Optimized and interpolated values of a, k, and m are given in table 4.1.

Table 4.1.—Optimized and interpolated values of parameters *a*, *k*, and *m* for monthly maximum daily rainfall, Okeechobee hurricane gate 6[1]

Month	Parameter *a*	Parameter *k*
January	[2]-0.79122	[2]0.59812
February	-.61334	.63402
March	-.20842	.70110
April	.23697	.73984
May	[2].53614	[2].81014
June	.65680	.81155
July	.69271	.79064
August	.64615	.76916
September	[2].51952	[2].72835
October	.22100	.69125
November	-.21985	.64487
December	-.61866	.60782

[1]Optimized value for m=1.05785.
[2]Optimized parameter.

Optimized parameters were used to generate ten 100-year sets of values for each month, and the 10 largest values were abstracted from each set for each month. Since the parameter functions are seasonally continuous, quarter points were selected for presentation of the generated values. The 10 largest values from each of the 10 sets are shown in figures 4.2–4.5 for January, April, July, and October. Comparisons of the generated and observed maximums show the effects of simultaneous fitting of the 12 monthly distributions and the resultant smoothing. The effects of the long tails of the distributions are reflected in the April and July data.

The generated data show a rather narrow range for return periods up to 50 years, but the range is considerably greater for the 100-year return period. This demonstrates the relative reliability of estimating the values for long recurrence intervals from the 43-year record.

The most significant point of the frequency analysis is that there is not a single value of estimated daily rainfall for any return period, but rather a range of values. This fact should be kept in mind when estimating future rainfall events from historical records.

A similar analysis was attempted using the monthly maximum daily rainfall data for Taylor Creek rain-gage 3 (table A-9). However, the short period of record (1955–72) resulted in relatively flat histograms, regardless of class widths, and optimization of parameters could not

be obtained. This further demonstrates the need for relatively long-term records for frequency analysis.

4.1.2.—Areal Distribution of Precipitation

Rainfall amounts for hydraulic design are normally taken from point-rainfall data or published National Weather Service[1] maps based on point-rainfall analyses (*19*). Basin

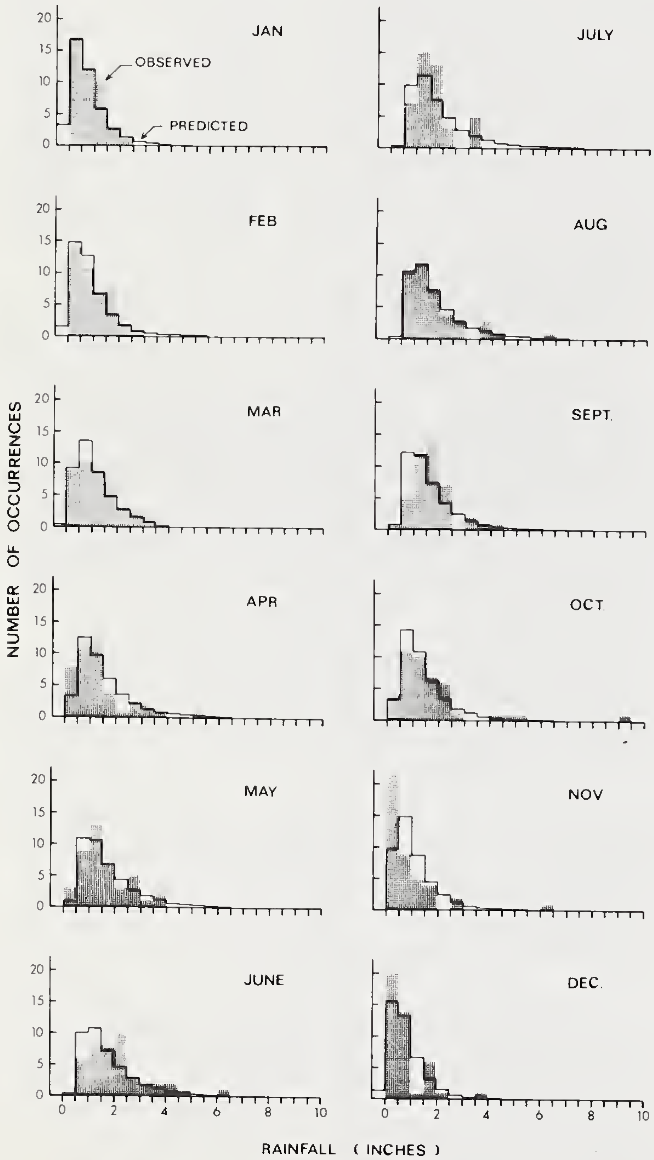

FIGURE 4.1.—Observed and calculated histograms for monthly minimum daily rainfall, Okeechobee hurricane gate 6, 1930–72.

[1]Formerly U.S. Weather Bureau (USWB).

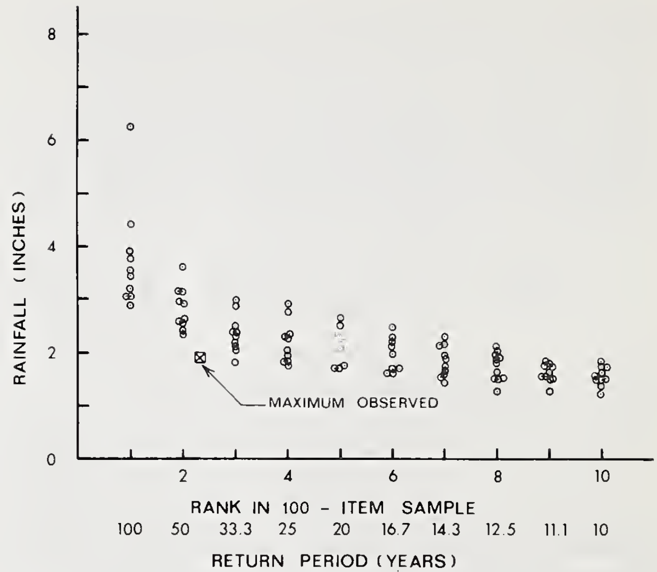

FIGURE 4.2.—Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, January.

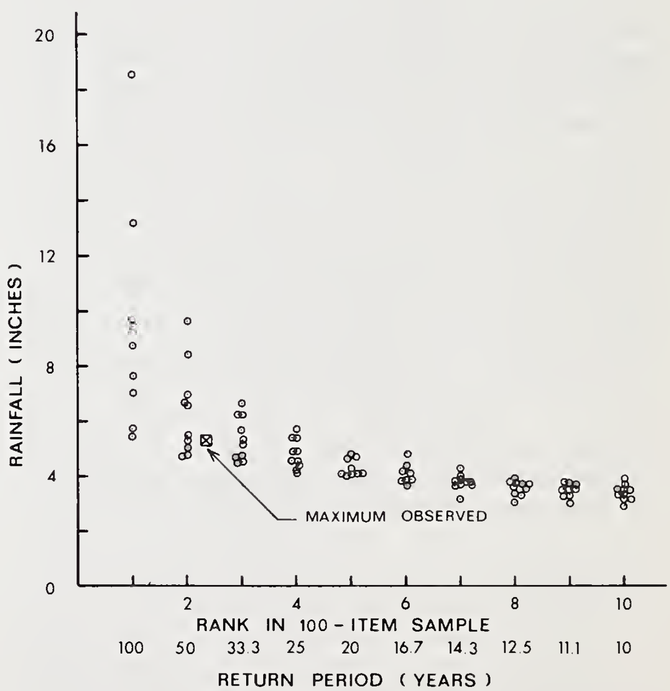

FIGURE 4.3.—Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, April.

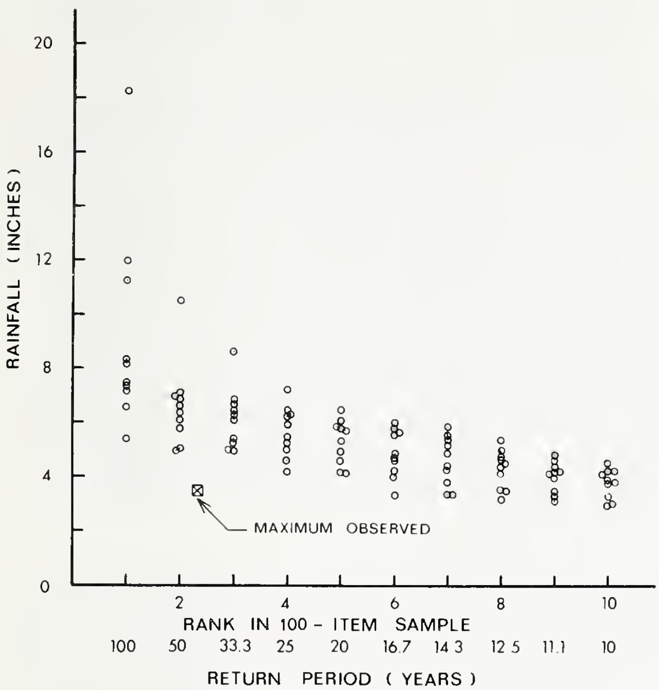

FIGURE 4.4.—Maximum generated daily rainfall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, July.

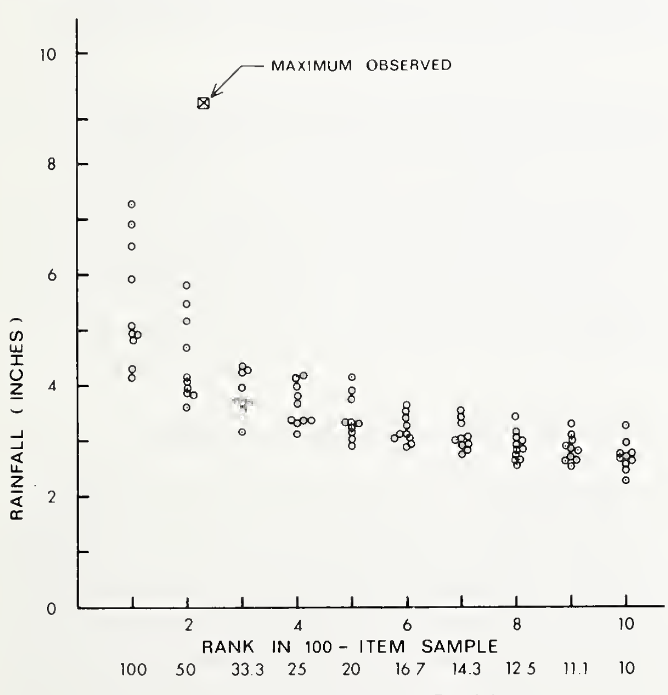

FIGURE 4.5.—Maximum generated daily rain-fall, 10 maximums from ten 100-year samples, Okeechobee hurricane gate 6, Oct.

or watershed rainfall is generally determined by reduction of point-rainfall estimates by some predetermined factor dependent on climatic region. SCS has developed criteria for reducing point rainfall to areal rainfall for three climatic regions (*60*). The Taylor Creek watershed is in the humid and subhumid region. Since there have been but few rain-gage networks in existence, few data are available for determination of reduction ratios. Although the Taylor Creek network has not had a high density of gages and the record period is relatively short, the data provide some estimate of reduction ratios.

Daily- and storm-rainfall data were used for areal-to-point rainfall analysis. All storms selected were those in which maximum observed point rainfall equaled or exceeded 2.00 inches, irrespective of storm duration. Storms were analyzed for each month of the year in order to determine if season or storm type affected the area-to-point relation. The 2-inch lower limit was too low to be significant for design purposes, but a higher limit would have resulted in no storms for some months. For example, there were no storms in January or November with rainfall amounts greater than 3.00 inches. The largest storm on record, one associated with a tropical storm, occurred in October 1956 when the maximum point rainfall was 11.40 inches.

Although hurricanes are common in Florida and the magnitude of the 1956 storm was not exceptionally great, such rainfall amounts occur very infrequently. Watershed rainfall for the storm, determined by the Thiessen method, was 11.32 inches for subwatershed W–3, 9.72 inches for subwatershed W–5, and 8.76 inches for watershed W–2.

Ratios of areal rainfall to point rainfall exhibited a wide range, especially in the summer months. This is expected for the convective type of thunderstorms that occur in the area. The largest ratios generally occur in March when storms are associated with frontal movement. Maximum ratios for each area, irrespective of month, are shown in figure 4.6. The line shows that little or no reduction can be used up to about 100 square miles. Ratios for the largest storm are also shown in figure 4.6 along with the SCS curve for humid and subhumid climate. Comparison of the curves indicates that an overreduction would result from use of the line for humid and subhumid climate for areas up to about 85 square miles. Disregarding known tropical storms, a few storms of 4- to 5-inch magnitude occurred in which ratios for the 15.7-square-mile area (W–3) and the 35.4-square-mile area (W–5) were considerably greater than those for the humid and subhumid

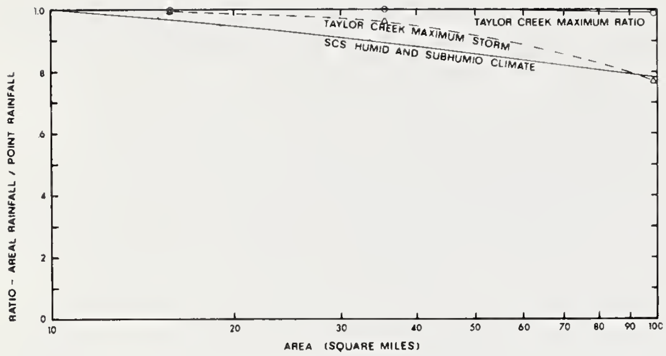

FIGURE 4.6.—Relationship between ratio of area-to-point rainfall and size of area, Taylor Creek watershed.

climate. A denser rain-gage network undoubtedly would show different results, but the length of record helps offset shortcomings in gage density.

Based on the results of this study, caution should be exercised in selection of reduction factors for hydraulic design purposes. These data should be representative of much of the Coastal Flatwoods areas, particularly peninsular Florida, and the data can be used with confidence.

4.1.3.—Storm-Rainfall Duration

Hourly rainfall data for rain-gage 4 were studied to determine probable storm duration. An arbitrary definition was assumed in order to categorize storms, as follows: any period of rainfall with less than a 3-hour lapse without rainfall. This is different from the classical USWB definition in that the lapsed period without rainfall is 3 hours rather than 6 hours. The 3-hour lapse was selected because a preliminary scanning of the data revealed that many storms of 1-hour duration are isolated in space and time. Most storms in the Taylor Creek watershed, and peninsular Florida as a whole, are small in areal extent. Several storm cells develop at different times over a large area and result in what would normally be called intermittent rain. However, examination of records from rain-gage networks show these storms to be from different cells. This is typical of convective-thunderstorm rainfall.

The record period July 1955 through December 1974 was used for rain-gage 4 in order to get the longest record possible, and thus the most storms. A total of 1,961 storms, as defined above, occurred during the record period. Since hourly rainfall data were used, 1 hour was the shortest duration that could be detected. The storms ranged from 1 to 41 hours in duration. Determinations were made by month to detect different storm types, if possible. The shortest durations occurred in July, with a maximum duration of 10 hours. The months of May and August had the next shortest durations with maximums of 15 and 16 hours, respectively. This is typical of summer thunderstorm rainfall. Tropical storms may occur during the months of June through October, and some did occur during the record period. The two longest June storms were of 28 and 36 hours duration and were associated with tropical storms. Only 8 of the 1,961 storms had durations greater than 24 hours. Only 43 storms lasted longer than 12 hours, and only 184 storms lasted longer than 6 hours. One-hour storms accounted for 39 percent of the total, with 1- and 2-hour durations making up 59 percent of the total (table 4.2). Ninety-one percent were of 6 hours or less duration.

An arbitrary decision was made to determine significant storms based on storm-rainfall amount. Storms with rainfall equal to or greater than 1.0 inch, irrespective of duration, were considered significant. The numbers of significant storms by duration are given in table 4.3. Only 11 percent of the total number of storms were considered significant, based on the above criteria. Storms with durations of 12 hours or less accounted for 85 percent of the significant events, and storms with durations of 6 hours or less accounted for 64 percent.

The largest storm event occurred in October 1956 when a tropical storm produced 8.94 inches of rainfall in 24 hours. The total storm period was 37 hours, with a 3-hour interval without rainfall early in the storm. The total observed rainfall in 37 hours was 9.14 inches. In July 1972, a 1-hour storm produced 2.46 inches, which was the largest amount for a 1-hour period. The longest duration, 41 hours in February 1964, resulted in only 2.02 inches.

4.1.4.—Time Distribution of Storm Rainfall

Time distribution of storm rainfall has received little attention in the past. Design storms are usually distributed in time by some fixed advanced, intermediate, or delayed criterion to determine which gives the worst hydrologic condition for water resources planning and hydraulic design. In 1969, Speir et al. (*46*) categorized storms into those with durations of less than 12 hours and those with durations of more than 12 hours. Time distribution curves representing the usual (model) patterns for high-intensity storms are shown in figure 4.7. The 15 largest magnitude

Table 4.2.—Monthly number of storms by duration, rain-gage 4, July 1955–December 1974

Duration (hours)	Month												Total	Cumulative percent
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
1	38	39	27	38	65	94	122	115	88	70	36	37	769	39.21
2	11	13	19	13	35	52	70	62	52	31	19	19	396	59.41
3	7	12	16	11	19	38	36	34	29	26	4	10	242	71.75
4	7	8	14	10	12	26	20	24	21	13	9	11	175	80.67
5	8	9	9	3	10	14	14	19	15	12	6	4	123	86.95
6	6	5	9	0	4	14	6	7	11	5	1	6	74	90.72
7	4	3	3	1	4	4	5	9	8	6	3	1	51	93.32
8	5	5	3	2	2	4	4	1	7	2	2	0	37	95.21
9	2	2	1	2	4	1	2	0	6	3	0	0	23	96.38
10	3	2	1	0	1	1	1	0	2	2	0	0	13	97.04
11	0	1	0	1	0	0	0	0	1	0	1	0	4	97.25
12	1	0	3	0	1	1	0	0	3	2	0	0	11	97.81
13	2	1	0	0	0	1	0	1	1	0	1	1	8	98.22
14	0	0	0	1	0	2	0	0	0	1	0	1	5	98.47
15	0	0	0	0	1	0	0	0	1	0	0	0	2	98.57
16	1	1	0	0	0	0	0	1	0	1	0	0	4	98.78
17	0	1	1	0	0	0	0	0	0	1	0	0	3	98.93
18	0	0	1	0	0	1	0	0	0	0	0	0	2	99.03
19	0	1	0	0	0	0	0	0	0	0	0	0	1	99.08
20	0	0	0	0	0	1	0	0	0	2	0	0	3	99.24
21	0	0	0	0	0	1	0	0	0	1	0	0	2	99.34
22	0	0	0	0	0	0	0	0	0	0	1	0	1	99.39
23	0	0	0	0	0	0	0	0	0	0	0	1	1	99.44
24	1	0	0	1	0	0	0	0	0	1	0	0	3	99.59
25	0	0	0	0	0	0	0	0	0	0	0	1	1	99.64
26	0	0	0	0	0	0	0	0	0	0	0	0	0	99.64
27	0	1	0	0	0	0	0	0	0	0	0	0	1	99.69
28	0	0	0	0	0	1	0	0	0	0	0	1	2	99.80
29	0	0	0	0	0	0	0	0	0	0	0	0	0	99.80
30	0	0	0	0	0	0	0	0	0	0	0	0	0	99.80
31	0	0	0	0	0	0	0	0	1	0	0	0	1	99.85
32	0	0	0	0	0	0	0	0	0	0	0	0	0	99.85
33	0	0	0	0	0	0	0	0	0	0	0	0	0	99.85
34	0	0	0	0	0	0	0	0	0	0	0	0	0	99.85
35	0	0	0	0	0	0	0	0	0	0	0	0	0	99.85
36	0	0	0	0	0	1	0	0	1	0	0	0	2	99.95
37	0	0	0	0	0	0	0	0	0	0	0	0	0	99.95
38	0	0	0	0	0	0	0	0	0	0	0	0	0	99.95
39	0	0	0	0	0	0	0	0	0	0	0	0	0	99.95
40	0	0	0	0	0	0	0	0	0	0	0	0	0	99.95
41	0	1	0	0	0	0	0	0	0	0	0	0	1	100.00
Total	96	105	107	83	158	257	280	273	247	179	83	93	1,961	......

Table 4.3.—Monthly number of storms with rainfall ⩾1.0 inch, by duration, rain-gage 4, July 1955–December 1974

Duration (hours)	Month												Total	Cumulative percent
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
1	1	0	0	1	4	1	4	4	2	0	0	0	17	8.10
2	0	0	0	1	5	8	6	7	6	2	1	0	36	25.24
3	0	1	3	0	5	12	2	5	1	3	0	0	32	40.48
4	0	0	1	1	3	4	5	3	2	1	1	0	21	50.48
5	1	0	2	2	2	4	2	0	2	4	0	3	22	60.95
6	1	0	1	0	1	3	2	2	3	0	0	0	13	67.14
7	0	1	1	0	3	0	1	2	2	2	0	0	12	72.86
8	2	0	1	0	0	1	3	0	1	0	1	0	9	77.14
9	0	1	0	0	2	0	0	0	5	1	0	0	9	81.43
10	2	0	1	0	1	0	0	0	1	0	0	0	5	83.81
11	0	0	0	1	0	0	0	0	0	0	1	0	2	84.76
12	0	0	1	0	1	1	0	0	2	1	0	0	6	87.62
13	1	0	0	0	0	0	0	1	0	0	1	1	4	89.52
14	0	0	0	0	0	1	0	0	0	1	0	0	2	90.48
15	0	0	0	0	1	0	0	0	0	0	0	0	1	90.95
16	0	0	0	0	0	0	0	1	0	0	0	0	1	91.43
17	0	1	1	0	0	0	0	0	0	0	0	0	2	92.38
18	0	0	1	0	0	1	0	0	0	0	0	0	2	93.81
19	0	1	0	0	0	0	0	0	0	0	0	0	1	93.81
20	0	0	0	0	0	0	0	0	0	1	0	0	1	94.29
21	0	0	0	0	0	1	0	0	0	1	0	0	2	95.24
22	0	0	0	0	0	0	0	0	0	0	0	0	0	95.24
23	0	0	0	0	0	0	0	0	0	0	1	1	2	96.19
24	1	0	0	0	0	0	0	0	0	1	0	0	2	97.14
25	0	0	0	0	0	0	0	0	0	0	0	1	1	97.62
26	0	0	0	0	0	0	0	0	0	0	0	0	0	97.62
27	0	0	1	0	0	0	0	0	0	0	0	0	1	98.10
28	0	0	0	0	0	1	0	0	0	0	0	0	1	98.57
29	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
30	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
31	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
32	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
33	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
34	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
35	0	0	0	0	0	0	0	0	0	0	0	0	0	98.57
36	0	0	0	0	0	1	0	0	1	0	0	0	2	99.52
37	0	0	0	0	0	0	0	0	0	0	0	0	0	99.52
38	0	0	0	0	0	0	0	0	0	0	0	0	0	99.52
39	0	0	0	0	0	0	0	0	0	0	0	0	0	99.52
40	0	0	0	0	0	0	0	0	0	0	0	0	0	99.52
41	0	1	0	0	0	0	0	0	0	0	0	0	1	100.00
Total	9	6	14	6	28	39	25	25	28	18	6	6	210	......

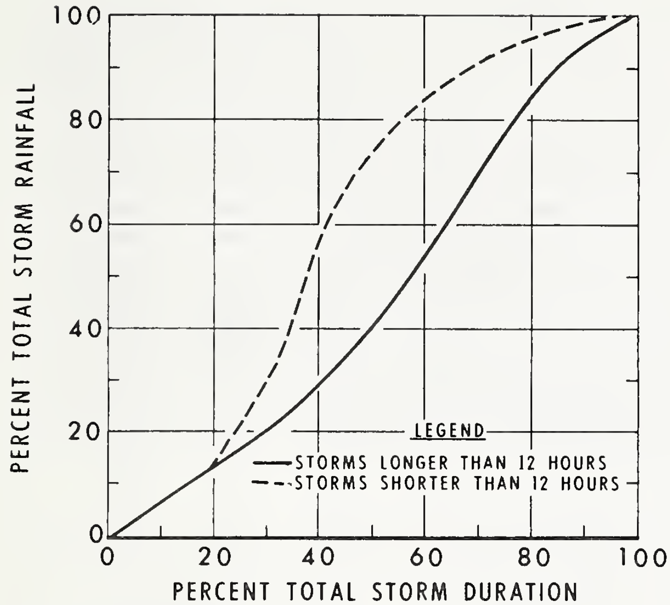

FIGURE 4.7.—Time-distribution curves representing usual patterns for high-intensity rainfall.

storms on record at that time were used in developing the distributions. Knisel and Snyder (*26*) and U.S. Agricultural Research Service (*55*) considered successive accumulations of storm rainfall as stochastic variates. Statistical distributions of accumulated rainfall were developed at 2-hour intervals, and these were fitted with three-parameter log-normal distribution. Two of the three parameters were expressed as continuous functions of time after beginning of rainfall and were evaluated by the method of nonlinear least squares. After evaluation, stochastic patterns of storm rainfall were simulated. The study considered 24-hour storm durations and arbitrary summer and winter seasons to distinguish between storm types. The method produced seemingly good results at three locations in the southeastern United States.

Based on the storm-duration analysis in section 4.1.3, a storm in the Taylor Creek area seldom lasts more than 12 hours; thus, a 12-hour duration was used in the present analysis. A 1-hour time interval was assumed. The convective-thunderstorm rainfall in peninsular Florida is generally shorter in duration. The two seasons were arbitrarily assumed as follows: summer, June 1 through September 30, and winter, October 1 through May 31. These seasons correspond roughly to the normal "wet" and "dry" seasons, respectively.

Hourly rainfall data at Taylor Creek rain-gage 4 (fig. 1.3) were used in the analysis. All storms with rainfall amounts equal to or greater than 1.0 inch in 12 hours were selected. These criteria resulted in 131 summer storms and 95 winter storms. The data were organized into histograms for each 1-hour interval, with an assumed class width of 0.25 inch.

The three-parameter log-normal distribution function was used for fitting distributions of cumulative storm rainfall amounts at 1-hour time intervals within the storms. The log-normal probability density function and the variate transform function are given in equations 4.1 and 4.2, respectively. As in the previous studies, parameters a and k were expressed as functions of time interval. Functional forms used by Knisel and Snyder (*26*) for 24-hour-duration storms were tested in the present study. Because of the high-peaked nature of the histograms, test criteria had to be relaxed in order to achieve evaluation. Other forms for the parameters were tested, but they did not result in a better fit of the observed data.

The boundary parameter, a, is given by

$$a_i = LCL - b_1\{\exp\,[-b_2(i-1)^2]\}\ , \tag{4.3}$$

and the scale parameter, k, is

$$k_i = \frac{C_1}{i} + C_2\ , \tag{4.4}$$

where LCL is the class limit corresponding to the minimum storm selection criterion, i is the i^{th} 1-hour time interval, and b_1, b_2, C_1, and C_2 are mathematical coefficients. As in the previous study, parameter m, the mean of the embedded normal, was made constant for all 12 distributions. Optimum values of the mathematical coefficients b and C and parameter m, from simultaneous fitting of the 12 distributions, are given in table 4.4 along with correlation coefficients for each season. Values of the coefficients, particularly for b_2 and C_1, show considerable difference between seasons.

Table 4.4.—Optimum values of mathematical coefficients b and C and parameter m and values of correlation coefficients for each season, rain-gage 4

Season	Mathematical coefficients					Correlation coefficient
	b_1	b_2	C_1	C_2	m	
Summer . . .	4.00288	0.07156	0.58797	0.45540	2.06189	0.8090
Winter	4.38949	.02923	.03158	.63153	2.09770	.8282

Observed and calculated histograms for summer and winter storms are shown in figures 4.8 and 4.9, respectively. The high number of occurrences in a single class interval and subsequent rapid decrease in the next time interval cannot be fitted very accurately with the log-normal distribution. The observed histograms (figs. 4.8 and 4.9) emphasize the general short duration of storms, generally much less than 12 hours.

Optimized values of the coefficients and parameters in table 4.4 were used with a random-number generation procedure to generate synthetic storm data. Sets of 50 storms were generated for each season. The generated summer storms are given in table 4.5, and the winter storms are given in table 4.6. All of the generated summer storms are realistic except storm 31, which shows 11.53 inches of rainfall in the first hour. Such extremes are likely to occur in generation techniques when some limit is not set. The generated values shown in tables 4.5 and 4.6 are not limited. The synthetic storm rainfall data are characteristic of observed storms in that some storms have a 1-hour duration, some have lapsed time intervals without additional rainfall, and others have a 12-hour duration. A significant difference between the summer and winter synthetic values is evidenced by the low first-hour values for winter. Overall durations are generally longer in winter, which typifies actual occurrence. The synthetic data in tables 4.5 and 4.6 can be used in testing storm rainfall-runoff models and in predictions of storm hydrographs.

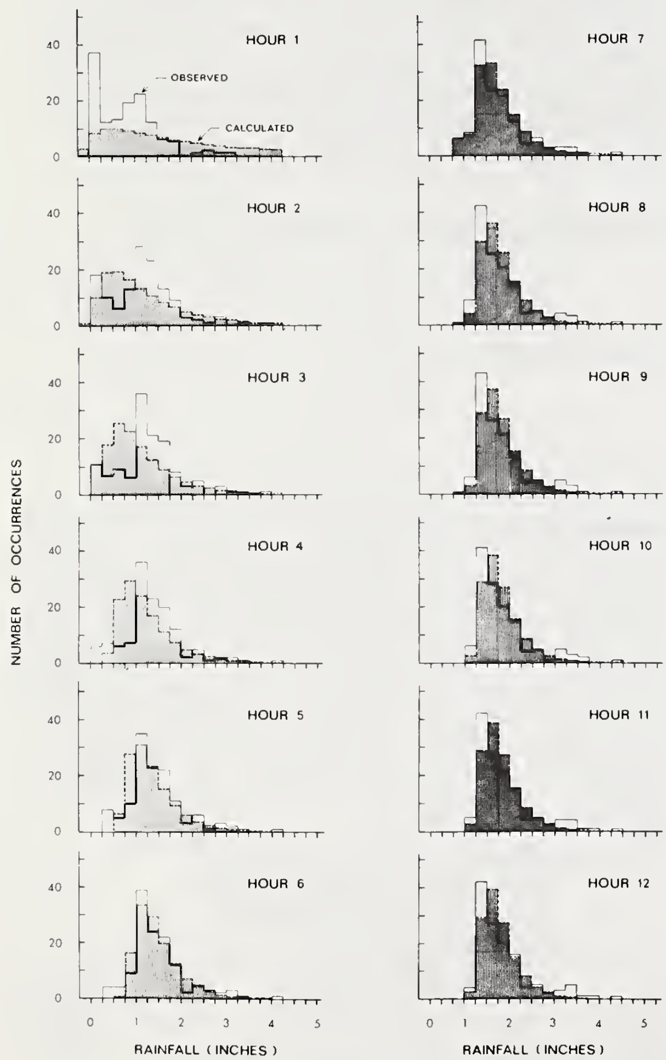

FIGURE 4.8.—Observed and calculated histograms for summer-storm rainfall, rain-gage 4.

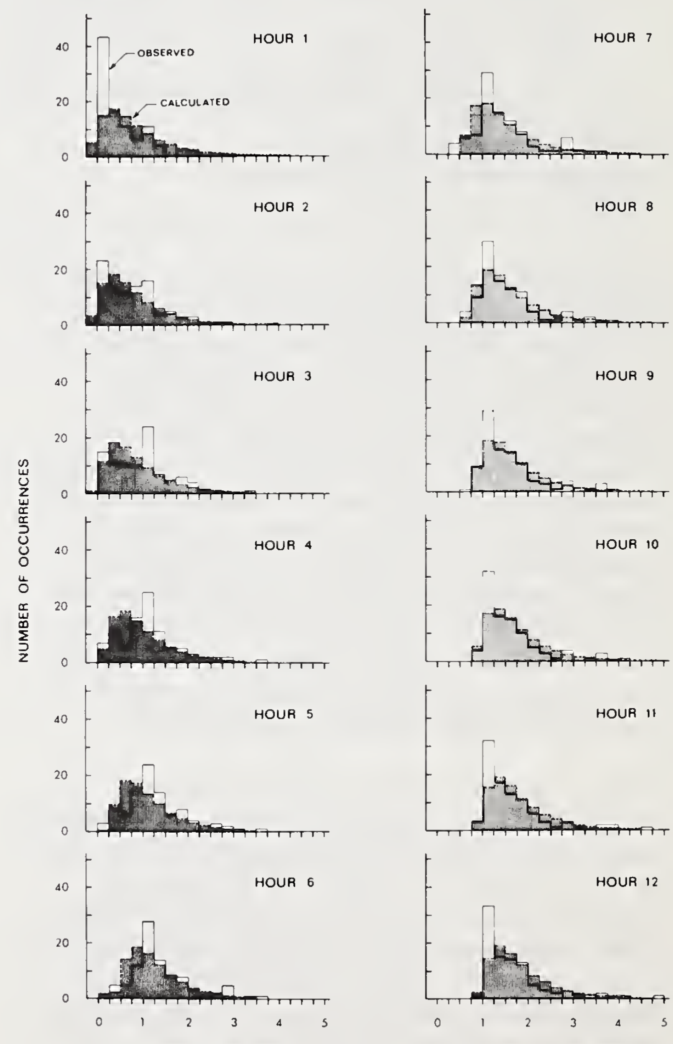

FIGURE 4.9.—Observed and calculated histograms for winter-storm rainfall, rain-gage 4.

Table 4.5.—Rainfall of fifty 12-hour synthetic summer storms at 1-hour intervals, rain-gage 4

Storm	Inches of rainfall at hourly interval No.—											
No.	1	2	3	4	5	6	7	8	9	10	11	12
1	2.13	2.13	2.13	2.13	2.13	2.64	2.64	2.64	2.64	2.64	2.64	2.64
2	1.53	1.53	1.53	1.56	1.56	1.56	1.56	2.19	2.19	2.19	2.19	2.19
3	.80	.97	1.43	1.43	1.43	1.90	1.90	1.90	1.90	1.90	2.04	2.04
4	.72	1.45	1.45	1.45	1.77	1.77	2.53	2.53	2.53	2.53	2.53	2.53
5	.58	.58	1.66	1.66	1.84	1.84	1.84	1.84	1.84	2.01	2.01	2.01
6	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
7	1.37	1.37	1.37	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
8	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24	5.24
9	1.78	2.08	2.08	2.08	2.08	2.08	2.76	2.76	2.76	2.76	2.76	2.76
10	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94
11	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51
12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
13	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
14	1.59	1.59	1.59	1.59	1.59	1.59	1.67	1.73	1.73	2.04	2.04	2.04
15	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
16	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27
17	1.31	1.37	1.37	1.37	1.37	1.65	2.40	2.40	2.40	2.40	2.40	2.40
18	1.15	1.63	2.21	2.21	2.21	2.22	2.22	2.22	2.22	2.22	2.22	2.22
19	1.60	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
20	.44	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
21	2.11	2.11	2.11	2.11	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
22	1.76	1.76	1.76	1.76	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
23	.15	.45	1.05	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33
24	.75	.75	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
25	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31
26	.83	1.96	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
27	.01	2.28	2.28	2.42	2.42	2.42	2.46	2.46	2.46	2.46	2.46	2.46
28	1.20	1.20	1.20	1.58	1.58	1.58	2.71	2.71	2.71	2.71	2.71	2.71
29	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.97	2.97	2.97
30	2.60	2.60	2.60	2.60	2.60	2.60	2.62	2.62	2.62	2.62	2.62	2.62
31	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53
32	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42
33	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28
34	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
35	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
36	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
37	.41	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98
38	.61	.61	.61	1.98	1.98	1.98	2.05	2.05	2.05	2.05	2.05	2.05
39	.34	.56	.56	.91	1.60	1.60	1.96	1.96	1.96	1.96	1.96	1.96
40	2.66	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01
41	.25	1.13	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
42	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57
43	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
44	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63
45	1.78	1.78	1.78	1.78	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
46	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
47	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07
48	1.07	1.07	1.07	1.20	1.20	1.32	1.73	1.73	1.73	1.73	1.73	1.83
49	.35	1.25	1.25	1.25	1.25	1.35	1.90	1.90	1.90	1.90	1.90	1.90
50	1.87	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77

4.1.5.—Climatic Drought

Definition of a drought varies with the user and depends on the purpose for which it is intended. Those interested in water supply base their definitions on some time period of minimum streamflow. Agriculturalists define drought in terms of rainfall or soil water that results in reduced crop yield. Such a definition varies with the particular crop,

Table 4.6.—Rainfall of fifty 12-hour synthetic winter storms at 1-hour intervals, rain-gage 4

Storm	Inches of rainfall at hourly interval No.—											
No.	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00	1.00	1.00	1.00	1.00	2.68	2.68	2.68	2.68	2.68	2.68	2.68
2	.17	.73	.73	1.68	1.68	1.68	1.97	1.97	2.28	2.28	3.81	3.81
3	1.71	2.13	2.13	2.13	2.13	2.13	2.13	2.37	2.37	2.37	2.37	2.37
4	.36	.42	1.10	1.10	1.58	1.58	1.69	1.69	1.69	1.96	1.96	1.96
5	.15	1.88	1.88	1.88	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53
6	2.14	2.14	2.14	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39
7	.67	.96	2.91	2.91	2.91	2.91	2.91	2.91	3.28	3.28	3.28	3.28
8	.60	.60	.73	.77	1.78	1.78	3.17	3.17	3.17	3.17	3.17	3.17
9	.46	.46	.73	1.77	1.77	1.77	1.77	1.82	1.82	2.58	3.42	3.42
10	.86	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.32
11	.70	.70	.70	.70	.70	3.85	3.85	3.85	3.85	3.85	3.85	3.85
12	1.58	1.58	1.58	1.58	1.73	1.73	1.73	1.73	1.73	1.85	1.85	2.28
13	.36	.89	1.83	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
14	1.45	1.45	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	3.45
15	.29	1.13	1.13	1.13	1.13	1.15	1.80	1.80	1.91	1.91	1.95	1.95
16	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	2.12	4.23	4.23	4.23
17	1.37	1.37	1.37	1.37	1.37	1.37	2.09	2.09	2.09	2.09	2.09	2.79
18	.17	.46	.50	.62	.62	1.24	1.24	1.48	3.30	3.30	3.30	3.30
19	.21	.68	.68	.68	.68	1.02	2.76	2.76	2.76	2.76	2.76	4.23
20	.03	.05	1.00	1.00	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
21	.94	.94	.94	1.89	1.89	2.27	2.27	2.27	2.27	2.27	2.27	2.71
22	.90	.90	.90	.90	2.41	2.41	2.41	2.62	2.62	2.62	2.62	2.62
23	.05	.54	.89	.89	.89	1.06	2.40	2.40	2.40	2.84	2.84	2.84
24	.49	.52	1.47	1.47	1.47	1.47	1.58	1.58	1.60	2.84	2.84	2.84
25	.25	.39	.53	.91	1.19	1.22	1.34	1.58	1.58	2.48	2.48	2.48
26	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.60	1.93	1.93
27	.93	1.80	1.80	1.80	1.80	1.80	1.80	1.80	2.43	2.43	2.43	2.43
28	.65	1.17	1.17	1.17	1.17	1.75	2.02	2.02	2.02	2.02	2.02	2.37
29	.24	1.82	1.82	1.82	2.61	3.15	3.15	3.15	3.15	3.15	4.52	4.52
30	1.26	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
31	.22	.32	.60	1.56	1.56	1.56	1.56	2.18	2.18	2.18	2.18	2.18
32	.83	.95	.95	.95	1.17	1.55	1.75	1.75	1.76	1.76	1.76	2.43
33	1.47	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36
34	.74	1.75	1.75	1.75	1.75	1.75	1.75	3.16	3.16	3.16	3.16	3.16
35	.73	1.21	1.91	1.91	1.91	1.91	1.91	1.91	1.91	2.90	2.90	2.90
36	1.42	1.68	1.68	1.68	1.68	1.68	2.02	2.02	2.55	2.55	2.55	2.55
37	.24	1.54	1.54	1.54	1.54	1.54	1.54	1.54	2.89	2.89	2.89	3.82
38	.77	.77	.77	.77	.77	.97	1.20	1.28	1.28	1.59	1.59	1.71
39	.32	.32	1.01	1.01	1.01	1.01	1.01	2.19	2.19	2.31	2.31	2.31
40	.15	.28	1.05	1.05	1.34	1.34	1.43	1.43	1.43	1.43	2.21	2.21
41	.66	.66	.66	1.98	1.98	1.98	1.98	1.98	2.11	2.11	2.11	2.11
42	1.70	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.61	2.61
43	.92	1.22	1.22	1.22	1.22	1.22	1.22	2.75	2.75	2.75	2.75	2.75
44	.60	.67	1.12	1.15	2.01	2.07	2.07	2.07	2.07	2.07	2.44	2.44
45	.93	.93	1.41	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98
46	.74	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	2.30
47	.89	.89	1.41	2.98	2.98	2.98	2.98	2.98	2.98	3.73	3.73	3.73
48	.51	.63	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	3.31	3.31
49	.19	.23	.23	2.10	2.10	2.10	4.67	4.67	4.67	4.67	4.67	4.67
50	1.48	1.48	1.95	1.95	1.95	2.49	2.92	2.92	2.92	2.92	2.92	2.92

the soil type, and many other factors. It is impossible to adequately define an all-inclusive drought for all users. Palmer (*33*) developed criteria with monthly rainfall as input for comparison of drought periods. The method relies on subjective relativity to determine severity and length of drought, which are based on calculated runoff as opposed to observed runoff. The criteria are not specific values, and different users would get different results from the

same data. Also, the method does not provide information usable in frequency analysis. The USWB defined a drought as a period of 14 or more days with less than 0.25 inch rainfall in a 24-hour period (*56*).

The definition of drought in this report was designed to be useful for evaluating low rainfall effects on rain-fed agricultural crops that grow in Florida soils with low water-holding capacity. Since the maximum daily evapotranspiration of crops is about 0.25 inch, daily rainfall below this amount will have little impact on reducing crop water shortages. The objectives of this viewpoint of drought are not necessarily useful for regional water management and supply objectives, expect in decisions involving demand of water for irrigated agricultural crops.

A definition similar to that of the USWB is used here with slight modification. It is assumed that for the sandy soils of the Taylor Creek watershed, 0.25 inch of rainfall is adequate to provide some available water for some types of land use. The mean monthly rainfall histogram of figure 1.12 was used to give insight to seasonal rainfall amounts. In order to compare seasons or months, six 2-month periods were selected as follows: December–January, February–March, April–May, June–July, August–September, and October–November. The maximum number of consecutive days with less than 0.25 inch of rainfall at Okeechobee hurricane gate 6 was determined for each period each year. Histograms of drought

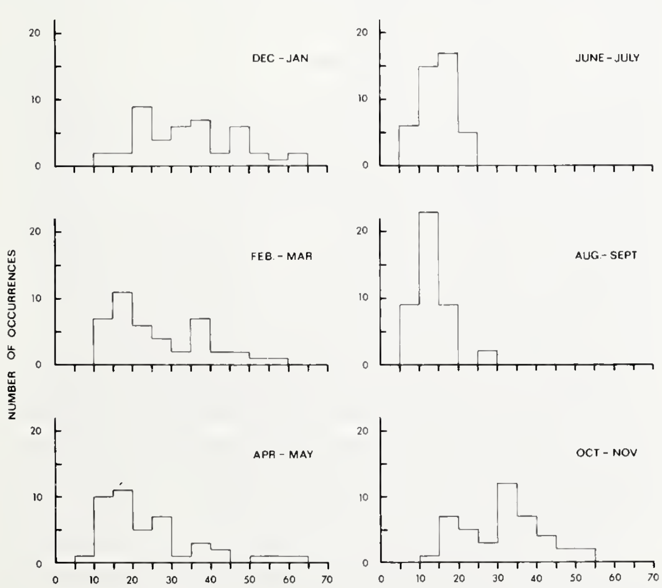

FIGURE 4.10.—Observed histograms of drought duration, Okeechobee hurricane gate 6.

length, developed for each 2-month period, are shown in figure 4.10. The histograms appeared to approximate the log-normal distribution, and since climate is cyclic over the year, it was desirable to fit the six histograms simultaneously.

An attempt was made to make parameters a and k of equations 4.1 and 4.2 functions of season, or bimonthly period. Several mathematical relations were tested, but results were poor since no form adequately reflected changes in the parameters by season. Therefore, we considered parameters a and k cyclic over the year but form-free by specifying three base values for each parameter and continuous parabolic interpolation of the intermediate values, as shown in table 4.7 (*41, 42*). Continuous parabolic interpolation required four base values, which produced the seasonally continuous cyclic system. The six observed histograms for Okeechobee hurricane gate 6 (fig. 4.10.) were fitted simultaneously by the method of least squares. In the simultaneous fitting, there were seven parameters to optimize, i.e., three base values each of a and k, and parameter m. Fitting the six periods individually would have required 18 parameters.

Table 4.7.—Schematic for seasonally continuous interpolation of bimonthly parameters in log-normal frequency distribution

Period	Base value		Interpolated value	
	a	k	a	k
Aug.–Sept.	a_5	k_5	....	....
Oct.–Nov.	....	....	....	....
Dec.–Jan.	a_1	k_1	....	....
Feb.–Mar.	....	....	a_2	k_2
Apr.–May	a_3	k_3	....	....
Jun.–July	....	....	a_4	k_4
Aug.–Sept.	a_5	k_5	....	....
Oct.–Nov.	....	....	a_6	k_6
Feb.–Mar.	....	....	....	....
Apr.–May	a_3	k_3	....	....

The fitted log-normal distribution functions were used to calculate the probabilities of several drought lengths for each period, as shown in table 4.8. The dry period of October through March is evident in the tabular probabilities. It should be reemphasized that this analysis represents a single definitive drought criterion. The definition as used seems inadequate for agricultural purposes. If soil-water data were available, a better analysis could be made on the probability of some minimum available soil water in the profile. Actually, drought is crop dependent as well as soil-water dependent. That is, some crops,

especially some of the vegetables, are less able than others to draw water from the soil profile. Likewise, depth of rooting is a major factor in agricultural drought. It is impossible to consider all kinds of drought in this paper thus the climatic drought was selected.

Table 4.8.—Probabilities (percent) for consecutive days with less than 0.25 inch of daily rainfall by bimonthly period

	No. of consecutive days				
Period	10	20	30	40	50
Dec.–Jan. ...	99.8	89.7	69.3	50.4	35.9
Feb.–Mar....	99.2	80.8	53.2	32.5	19.6
Apr.–May ...	94.8	48.4	16.5	5.2	11.7
Jun.–July....	84.7	15.3	1.4	.1	.01
Aug.–Sept. ..	82.5	8.5	.4	.01	<.01
Oct.–Nov....	98.8	67.7	32.1	13.8	5.9

4.1.6.—Probabilities of 5-Day Precipitation

The 43-year (1930–72) precipitation record at Okeechobee hurricane gate 6 was used to estimate probabilities for 5-day precipitation amounts. Five-day rainfall totals were determined for the period of record, and histograms were developed for each of the seventy-three 5-day periods of the year. The log-normal probability density function was used to approximate the distributions for each 5-day period. Since climate is a continuous process, parameters a and k in the probability density function (eq. 4.1) were considered seasonally continuous and cyclic over the year, and the 73 distributions were fitted simultaneously. Parameters a and k were optimized at five points during the year, with intermediate points determined by interpolation techniques (*42*). Parameter m, the mean of the embedded normal distribution, was considered constant over the year. The 11 parameters (five each for a and k and one for m) were optimized by the method of least squares. Simultaneously fitting the 73 distributions and optimizing all parameters, compared with 219 parameters if fitted independently, produces a fitting efficiency of about 20 to 1. Also, with simultaneous fitting, the probabilities are continuous between 5-day periods.

Probabilities of 5-day rainfall amounts greater than 0.5, 1.0, 2.0, and 3.0 inches are shown in table 4.9 for the seventy-three 5-day periods of the year. As shown in the table, probability of more than 0.5 inch is relatively low during the dry season, November through April. The beginning and ending of the rainy season varies from year to year, and although the average is June through September, it may begin in May and extend through October. During the rainy season, the probability of more than 3 inches of rain in a 5-day period is relatively high, reaching a maximum of 32.1 percent for the 44th period, August 4–8. During the dry season, there is less than a 4 percent probability of more than 3 inches of rainfall in 5 days.

Butson and Prine (*8*) published chance of occurrence for weekly rainfall greater than 0.5, 1.0, and 2.0 inches. Although the time interval was 7 days, compared with 5 days for the present study, the values agreed fairly well for the two studies. The estimated probabilities in table 4.9 can be used in water resource planning, i.e., irrigation requirements, runoff potential, water quality, etc. For example, the application of effluent from animal-waste lagoons onto land areas can be effective with minimum probable environmental degradation during October through March.

4.2.—Streamflow

Treatment of streamflow variables in this section is made purely on the basis of streamflow presentation. The section is intended to provide information and analyses of a specific variable without reference to interrelationships with precipitation or ground-water components. These interrelations are treated in later sections. Methodologies presented in earlier sections are cross-referenced without duplicating the details.

4.2.1.—Streamflow Duration

Streamflow duration analyses were made for watershed W–2 and W–3 before and after channelization and for W–5 after channelization. Streamflow measurements did not begin at W–5 until March 9, 1964. Channelization and construction of water-level control structures were completed in W–3 during Phase II, February–October 1964 (table A–10). Phase III did not include any work in W–3, but Phases II and III did include works below watershed W–3. After-treatment analysis for W–2 began July 1, 1968. The respective periods of flow-duration analysis for each watershed are given in table 4.10; the periods were selected for treatment and watershed comparisons.

Flow-duration curves are shown in figure 4.11 for watersheds W–2 and W–3 for the period of record before channelization, October 1, 1956, through January 31, 1964. The discharge values are in cubic feet per second per

Table 4.9.—Probability of precipitation greater than various amounts for each of seventy-three 5-day periods, Okeechobee hurricane gate 6

	Probability (percent) for precipitation greater than —								
Period	0.5 inch	1.0 inch	2.0 inch	3.0 inch	Period	0.5 inch	1.0 inch	2.0 inch	3.0 inch
Jan. 1–5	22.0	5.0	3.6	3.5	July 5–9	63.4	47.3	34.2	29.3
Jan. 6–10	22.2	5.1	3.6	3.6	July 10–14	64.1	48.2	35.2	30.1
Jan. 11–15	22.8	5.5	3.8	3.8	July 15–19	64.7	49.0	36.0	30.8
Jan. 16–20	23.8	6.0	4.1	4.1	July 20–24	65.1	49.7	36.6	31.4
Jan. 21–25	25.2	6.9	4.7	4.6	July 25–29	65.5	50.1	37.1	31.8
Jan. 26–30	26.5	7.8	5.2	5.1	July 30–Aug 3	65.7	50.4	37.4	32.1
Jan. 31–Feb. 4	28.2	9.0	5.8	5.8	Aug. 4–8	65.7	50.4	37.4	32.1
Feb. 5–9	30.0	10.3	6.6	6.5	Aug. 9–13	65.5	50.2	37.2	31.9
Feb. 10–14	31.8	11.7	7.4	7.2	Aug. 14–18	65.1	49.7	36.6	31.4
Feb. 15–19	33.7	13.3	8.4	8.1	Aug. 19–23	64.5	48.8	35.8	30.6
Feb. 20–24	35.5	15.0	9.3	8.9	Aug. 24–28	63.7	47.7	34.7	29.7
Feb. 25–Mar. 1	37.3	16.6	10.3	9.7	Aug. 29–Sept. 2	62.7	46.3	33.3	28.5
Mar. 2–6	38.9	18.2	11.2	10.5	Sept. 3–7	61.5	44.7	31.7	27.1
Mar. 7–11	40.4	19.7	12.1	11.6	Sept. 8–12	60.0	42.8	29.9	25.6
Mar. 12–16	41.8	21.1	13.0	12.0	Sept. 13–17	58.4	40.7	28.0	24.0
Mar. 17–21	43.0	22.4	13.9	12.7	Sept. 18–22	56.6	38.4	26.0	22.3
Mar. 22–26	44.1	23.5	1.46	13.3	Sept. 23–27	54.6	35.9	23.9	20.6
Mar. 27–31	45.2	24.7	15.4	14.0	Sept. 28–Oct. 2	52.5	33.3	21.8	18.9
Apr. 1–5	46.2	25.9	16.3	14.6	Oct. 3–7	50.3	30.7	19.7	17.3
Apr. 6–10	47.3	27.1	17.1	15.2	Oct. 8–12	48.1	28.1	17.8	15.8
Apr. 11–15	48.3	28.2	17.9	15.9	Oct. 13–17	45.9	25.6	16.1	14.5
Apr. 16–20	49.2	29.4	18.7	16.5	Oct. 18–22	43.9	23.4	14.6	13.3
Apr. 21–25	50.2	30.5	19.6	17.2	Oct. 23–27	42.2	21.5	13.3	12.5
Apr. 26–30	51.1	31.6	20.4	17.8	Oct. 28–Nov. 1	40.3	19.6	12.1	11.3
May 1–5	52.0	32.7	21.2	18.5	Nov. 2–6	38.4	17.7	11.0	10.4
May 6–10	52.9	33.7	22.1	19.2	Nov. 7–11	36.5	15.9	9.9	9.4
May 11–15	53.7	35.0	23.1	20.1	Nov. 12–16	34.6	14.1	8.9	8.5
May 16–20	54.5	35.8	23.7	20.5	Nov. 17–21	32.6	12.4	7.9	7.6
May 21–25	55.3	36.8	24.6	21.2	Nov. 22–26	30.8	11.0	7.0	6.9
May 26–30	56.1	37.8	25.4	21.9	Nov. 27–Dec. 1	29.0	9.6	6.2	6.1
May 31–June 4	56.9	38.8	26.3	22.6	Dec. 2–6	27.3	8.5	5.6	5.5
June 5–9	57.8	40.0	27.3	23.4	Dec. 7–11	25.9	7.4	5.0	4.9
June 10–14	58.8	41.2	28.5	24.5	Dec. 12–16	24.6	6.6	4.5	4.4
June 15–19	59.8	42.5	29.6	25.3	Dec. 17–21	23.5	5.9	4.1	4.1
June 20–24	60.8	43.8	30.9	26.4	Dec. 22–26	22.7	5.4	3.8	3.8
June 25–29	61.7	45.0	32.0	27.4	Dec. 27–31	22.2	5.1	3.6	3.6
June 30–July 4	62.6	46.2	33.2	28.4					

square mile for unit comparison of watershed characteristics. The unit comparison shows considerable differences in the medium- and low-flow ranges. The lower elevation at the W–2 gaging station provides more opportunity for prolonged profile drainage. Also, citrus irrigation in the lower part of W–2 (below W–3) may result in low-flow return during dry periods.

Comparisons of flow-duration curves were made for W–2 and W–3 before and after watershed treatment. Treatment

Table 4.10.—Periods of flow-duration analysis by watershed

Watershed	Treatment	Analysis period
W–2	Before-channelization	Oct. 1, 1956–Jan. 31, 1964
W–2	After-channelization	July 1, 1968–June 30, 1972
W–3	Before-channelization	Oct. 1, 1956–Jan. 31, 1964
W–3	After-channelization	Nov. 1, 1964–Dec. 31, 1972
W–3	After-channelization	July 1, 1968–June 30, 1972
W–5	After-channelization	July 1, 1968–June. 30, 1972

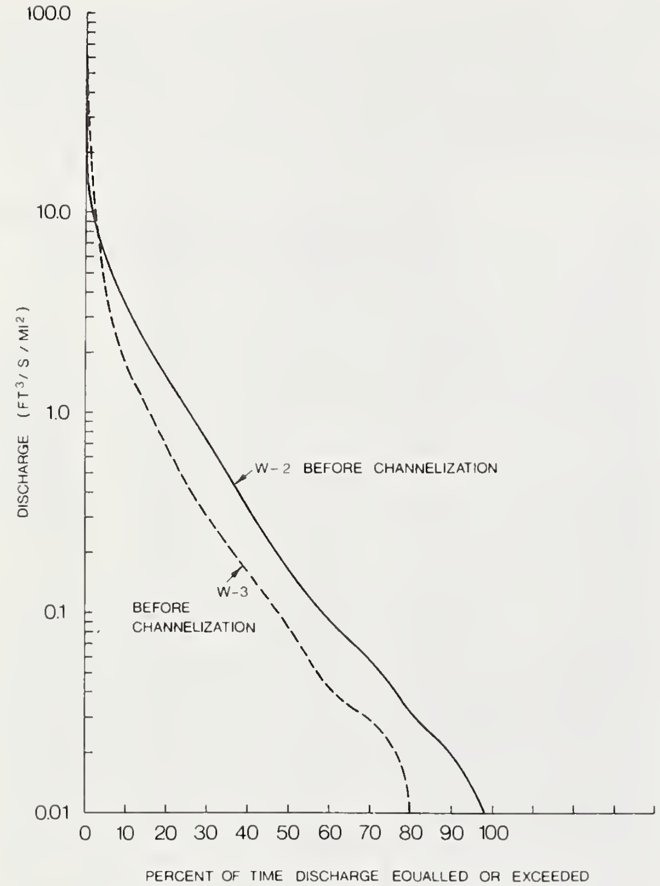

FIGURE 4.11.—Flow-duration curves, watershed W-2 and subwatershed W-3 before channelization.

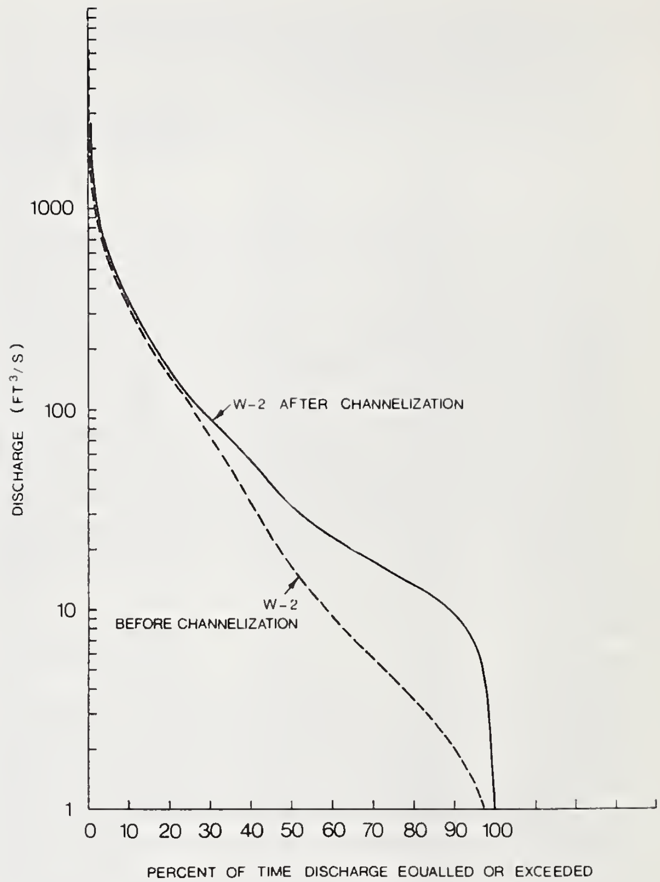

FIGURE 4.12.—Flow-duration curves, watershed W-2 before and after channelization.

effects on flow duration for W-2 are shown in figure 4.12. Low flows increased significantly after treatment. The increase reflects not only a changed flow regimen but a change in climate as well. The two curves begin diverging significantly at the 30-percent exceedance level. After channelization, high flows occurred during a larger percentage of the time. This was expected because of the increased drainage potential for storm runoff. The same general shift that occurred on W-2 was exhibited for W-3 in figure 4.13. Three periods were used in the flow-duration study for W-3, as shown in table 4.10. Channelization and water-level control structures resulted in a shift of the duration curve over the total after-treatment record period, 1964-72. An additional similar shift resulted for the shorter record period of 1968-72. Upstream extension of the Taylor Creek channel is probably responsible for the changes between the two periods. Evaluation of the three curves for W-3 form the basis for comparison of watersheds using the shorter after-treatment record.

Streamflow measurements were begun at W-5 on March 9, 1964. Most of the channelization within the watershed was completed by that date, but some construction continued in the area during Phase III (table A-10). Flow-duration curves for two periods, 1964-72 and 1968-72, are shown in figure 4.14 for comparison of periods. There is relatively little difference between the two curves in comparison with those for W-3. The differences for W-5 occur in the intermediate-flow range, whereas in the low-flow zone the two curves are almost identical. This probably reflects low return flows from irrigation of citrus in W-5.

Since flow-duration curves for W-3 and W-5 exhibit differences for the two periods after treatment and since construction in W-2 continued into 1968, watershed comparisons were made after treatment using the record period 1968-72. Discharges for the three watersheds were converted to cubic feet per second per square mile for

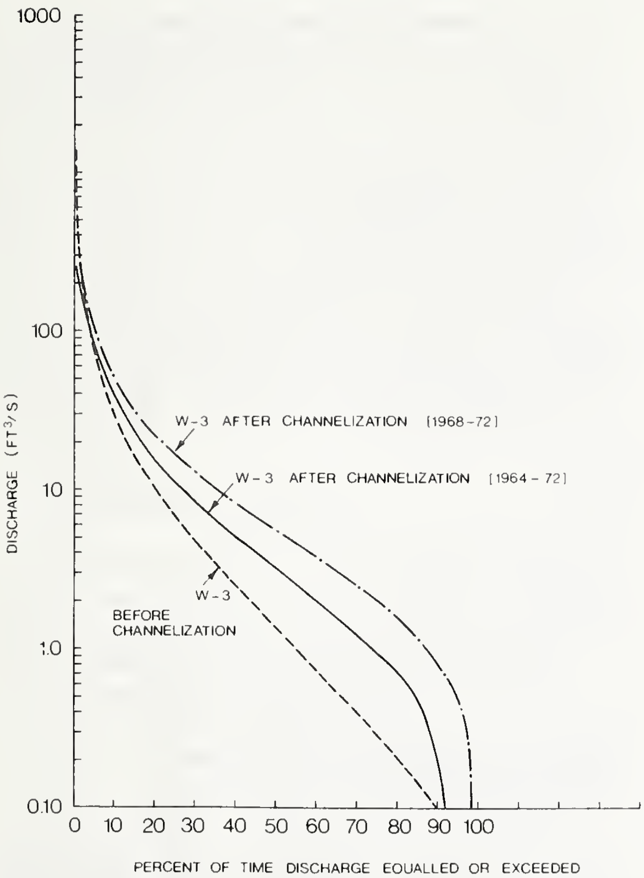

FIGURE 4.13.—Flow-duration curves, subwatershed W-3 before and after channelization.

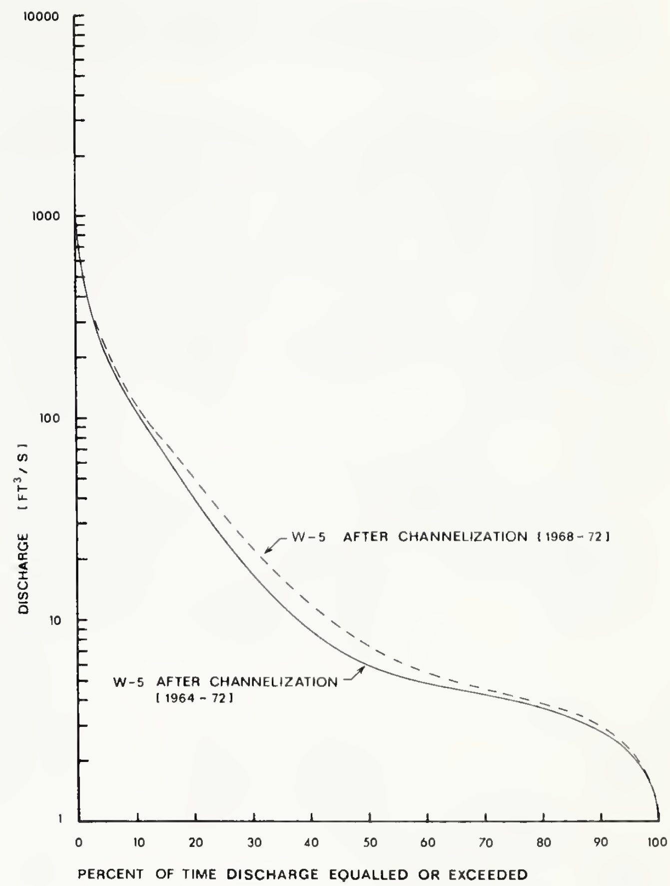

FIGURE 4.14.—Flow-duration curves, subwatershed W-5 after channelization.

unit comparison. The three flow-duration curves are shown in figure 4.15. Differences among the curves are not highly signficant and indicate that the flow regimens, with channelization and water-level control structures, are very similar for the three watersheds. The major differences occur in the low-flow range where irrigation-return flows are apparent in W-2 and W-5. Comparison of the W-2 and W-3 curves in figure 4.15 with those in figure 4.11 shows that the differences between W-2 and W-3 were not as great after channelization as they were before channelization. Channelization including the upstream extension of channel in W-3 and the water-level control structures obviously had an equalizing effect over the range of flows experienced. Also, the unit discharge near 100 percent of time after treatment (fig. 4.15) was higher than that for before treatment (fig. 4.11) which may have resulted from slow dewatering at the streambanks. Before channelization, the flood plain probably detained more water at low-flow conditions. In summary, flow-duration analyses show that channelization and water-level control structures resulted in higher discharges for given exceedance times. Low flows increased after treatment.

4.2.2.—Minimum Streamflow Frequency

Streamflow into lakes of central and southern Florida is an important part of the total water resource of the region, and low flows often become critical during dry seasons. Good resource planning must consider the recurrence of minimum flows. A frequency analysis of minimum streamflow was made for 7-, 14-, and 30-day periods.

Flow-duration analysis in the previous section showed that low flows slightly increased after channelization and construction of the water-level control structures. Even so, it is probably satisfactory to consider the full period of

FIGURE 4.15.—Flow-duration curves, watershed W-2 and subwatersheds W-3 and W-5 after channelization.

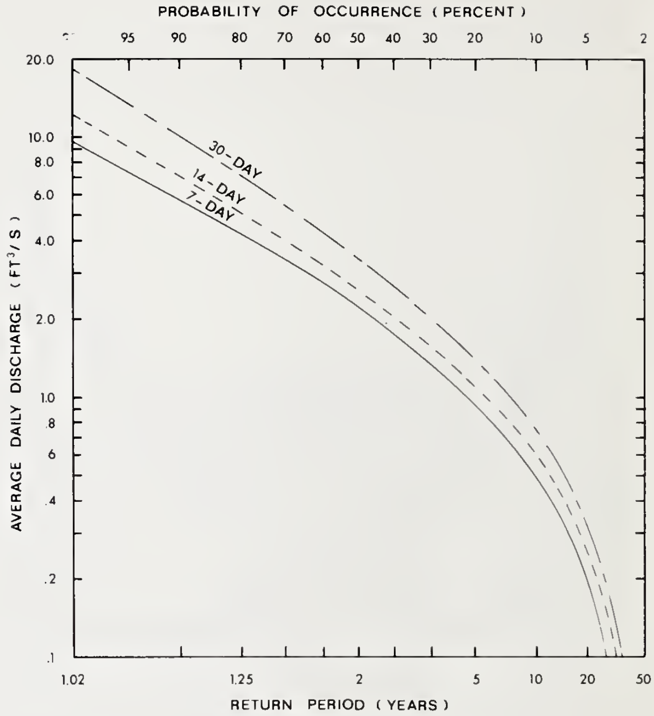

FIGURE 4.16.—Frequency of 7-, 14-, and 30-day minimum discharge, watershed W-2.

record for frequency analysis to give a more reliable estimate of minimum flows for longer return periods. Rainfall distribution during the year is a significant factor in minimum flows. Annual minimums for the 17-year period 1956–72 were reviewed for watersheds W-2 and W-3. It was determined that minimums during the after-treatment period were not higher than those during the before-treatment period. The least minimum for the longest duration occurred in 1956, but this reflects low rainfall during the dry season rather than treatment effects. As will be discussed in a later section, the largest flood also occurred in that same year. Minimum flows for the 7- and 14-day periods were determined for bimonthly periods corresponding to those considered in the climatic drought analysis of section 4.1.5. The resulting information provided insight into the time of occurrence. Most of the minimums occurred during the April-May period as would be expected, since the low-rainfall season extends from October through May. The lowest flows will normally occur late in that season. Annual minimums were determined for W-2 and W-3. It was found that, for mathematical purposes, streamflow at W-3 was zero in 12 of the 17 years for the 7-day period, in 10 for the 14-day period, and in 5 for the 30-day period. As was stated in 1969, frequency analysis is not normally practiced for such large percentages of zeros (*46*). No flow occurred in only 1 of the 17 years for the three durations at W-2, and the frequency analysis is restricted to that watershed. Annual minimums at W-2 occurred in April and May about 60 percent of the time.

The relatively short period of record does not work well with the frequency analysis method described in section 4.1.1, since the distributions are relatively flat. The procedure of Hazen (*18*) is used in the streamflow sections. The minimum-flow data were plotted on log-probability paper, with plotting position given by

$$P=\frac{2m-1}{2n}, \tag{4.5}$$

where m is the rank of the item in the series and n is the total number of items in the series. Skewness of the natural data made it necessary to adjust the data, and Hazen's method and table of logarithmic skew-curve factors were used. The resultant frequency curves are shown

in figure 4.16. Minimum average daily discharge for the 7-, 14-, and 30-day periods can be determined for the desired recurrence interval, as well as the relationships among the three time intervals. Comparison of the curves in figure 4.16 with those of the study published in 1969 shows that the estimated minimum flow in this study (figure 4.16) for all return periods is greater than those from the shorter period of record (*46*). This is attributable to the combined effects of the difference in rainfall, length of record, and the possible effects of increased low flows resulting from channel improvement and associated water-level control structures. However, the estimated values in figure 4.16 are appropriate for planning purposes.

4.2.3.—Flood-Flow Frequency

It was shown in section 3.2.2 that rainfall in the rainy season of May through October was greater in the before-treatment period than in the after-treatment period, and the conclusion was that comparisons of hydrologic response between periods might be biased. The streamflow-duration analysis in section 4.2.1 showed that a significant increase in low flows occurred after treatment, but there was little effect for high-flow durations. With all these factors in mind, it was concluded that flood-flow analysis can include the full record period of 1956–72 without significant bias.

As in the case of minimum-flow frequency, the relatively short record period does not work well with fitting frequency distributions by the method of least squares as described in section 4.1.1. Thus, the method for flood-flow frequency analysis was the same as that for minimum discharge in section 4.2.2. Hazen's procedure was used to determine probability (eq. 4.5), and skewness was adjusted using Hazen's table of logarithmic skew-curve factors (*18*).

Annual series of maximum instantaneous peak discharges and maximum mean daily discharges were used in the frequency analysis. The largest storm on record at watersheds W–2 and W–3 was the tropical storm of October 14–16, 1956. This storm resulted in the highest instantaneous peak and mean daily discharges. The second largest value of both series occurred in 1959, which was also in the before-treatment period. The next several values in order of magnitude occurred in the after-treatment period. The least annual value of both series at both watersheds occurred in 1961, which was during the before-treatment period. The distribution of values between periods indicates that little bias existed in using the full period of record.

Annual values of both series of discharges are shown in figure 4.17, along with the curves corrected for skew, for watershed W–2. The two frequency curves show little difference between the instantaneous and mean daily values. At the 20-year return period there is a difference of approximately 800 cubic feet per second and at the 5-year return period a difference of about 250 cubic feet per second. The difference is significant, however, at less frequent return periods for hydraulic design where discharge capacity is critical.

Figure 4.18 shows annual values and frequency lines for both series for subwatershed W–3. Although there is a wider separation of lines for W–3 than for W–2, the actual difference is about the same; i.e., 580 cubic feet per second at the 20-year return period and 340 cubic feet per second at the 5-year return period.

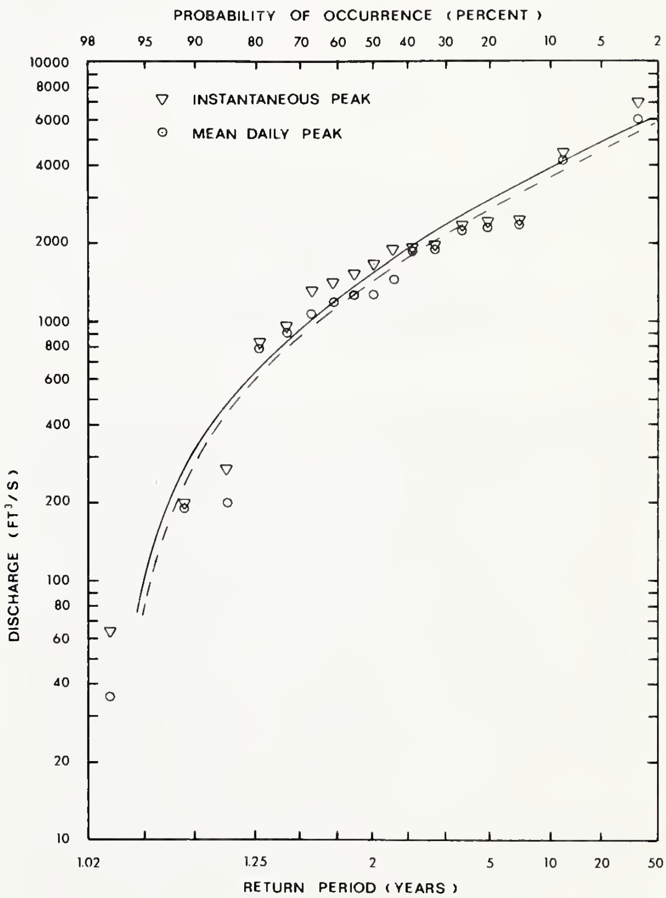

FIGURE 4.17.—Frequency of instantaneous and mean daily peak discharges, watershed W–2.

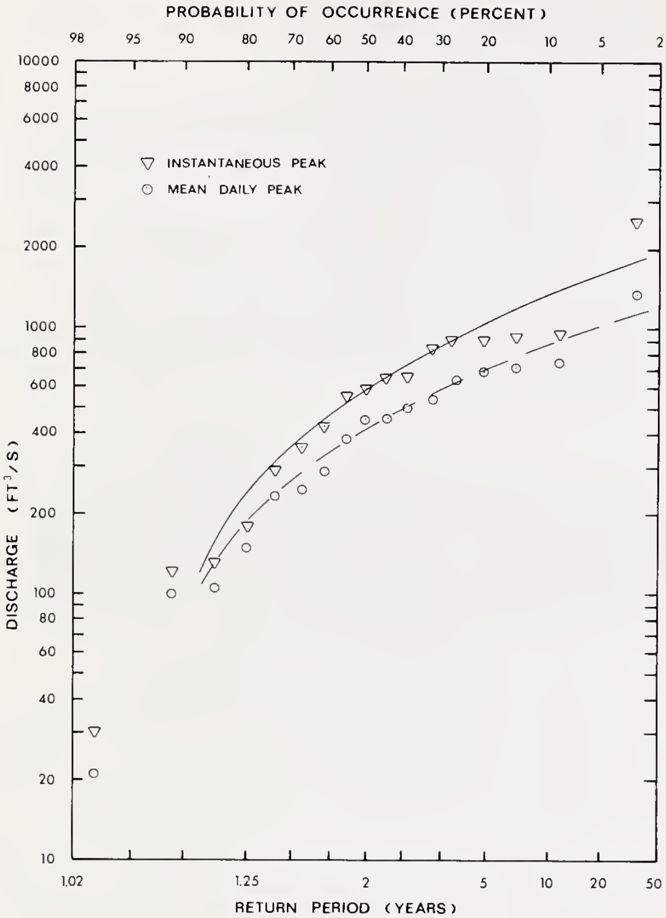

FIGURE 4.18.—Frequency of instantaneous and mean daily peak discharges, subwatershed W-3.

The 1956 maximum plot is considerably above the frequency curve for both of the above watersheds, which indicates a greater than 50-year return period. A study by the U.S. Army Corps of Engineers (unpublished data) revealed that the storm rainfall frequency was "slightly less than 100 years." The flood-frequency curves of figures 4.17 and 4.18 indicate that the 1956 peak discharges probably have a return period in the order of 100 years. Several tropical storms have occurred during the history of the Upper Taylor Creek watershed study, but none have compared in magnitude with the 1956 storm. The 1956 peak discharge at watershed W-2 was 1.6 times greater in magnitude than the second largest peak, which occurred in 1959. At W-3, the 1956 storm peak was 2.7 times greater than that of 1959.

Skewness of the frequency curves clearly shows the need for long-term hydrologic records for frequency analysis.

The sample size, or length of record, can be determined by

$$n=t^2 s^2/\bar{x}^2, \tag{4.6}$$

where n is the number of years, t is Student's T for any specified level of significance, s is standard deviation, and $\bar{x}$ is the mean (*38*).

SCS specified a 10-percent level of significance and developed a graphical procedure to estimate the length of record needed, based on the ratio of 100-year discharge to 2-year discharge (*60*). Using the graphical procedure with data from watershed W-2, we determined that 29 years of record are needed to be representative of a normal period. This test was used in other studies, and invariably it showed that longer records were needed, regardless of available length. We stress that the frequency curves developed from the 17-year record should be used with caution when extrapolating to longer return periods.

The log-Pearson III distribution was fitted to the annual maximum mean daily discharge for watersheds W-2 and W-3 (*61*). Computed skew coefficients were −1.44 and −1.30 for W-2 and W-3, respectively. Two- and fifty-year recurrence values, estimated for both watersheds, are shown in table 4.11. A comparison shows a maximum of 9.2 percent difference in estimated values. This relatively small difference could amount to a considerable difference in construction costs of a hydraulic structure. It is not known which values are more nearly correct.

Table 4.11.—Estimated recurrence values from fitting log-normal and log-Pearson III distributions and the percentages of difference in those values

Watershed and period	Distribution (ft³/s)		Difference in values (percent)
	Log-normal	Log-Pearson III	
W-2, 2-year	1,430	1,438	0.6
W-2, 50-year ...	5,800	5,312	9.2
W-3, 2-year	415	396	4.8
W-3, 50-year ...	1,200	1,211	.9

4.2.4.—Streamflow Volume Frequency

Agricultural drainage design is generally based on 24-hour runoff volumes for various return periods (*47*). Other drainage designs may use shorter or longer time units, depending on the severity of pondage for different lengths of time. Initial examination of the data revealed that the

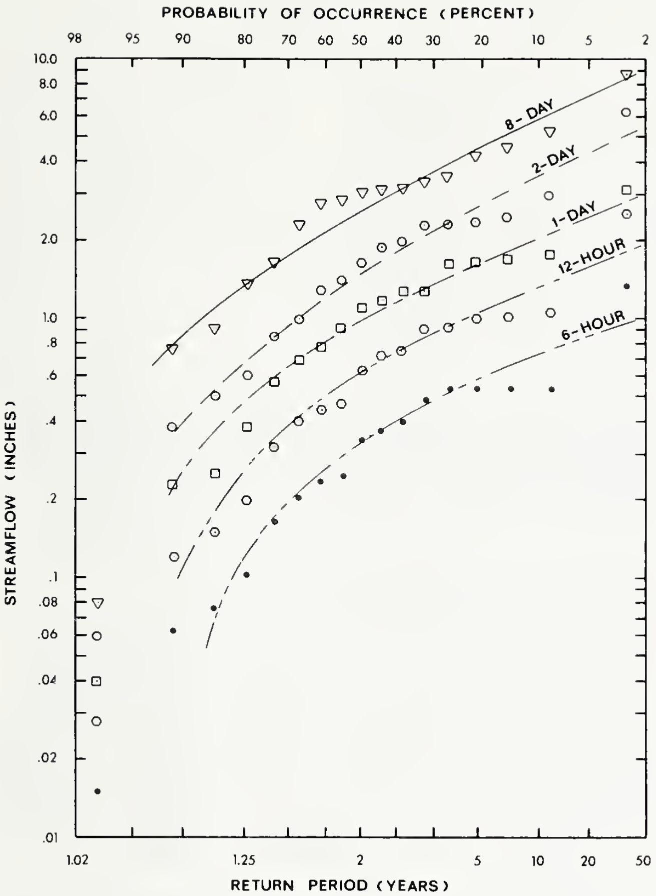

FIGURE 4.19.—Frequency of streamflow volumes for periods of 6 and 12 hours and 1, 2, and 8 days, watershed W-2.

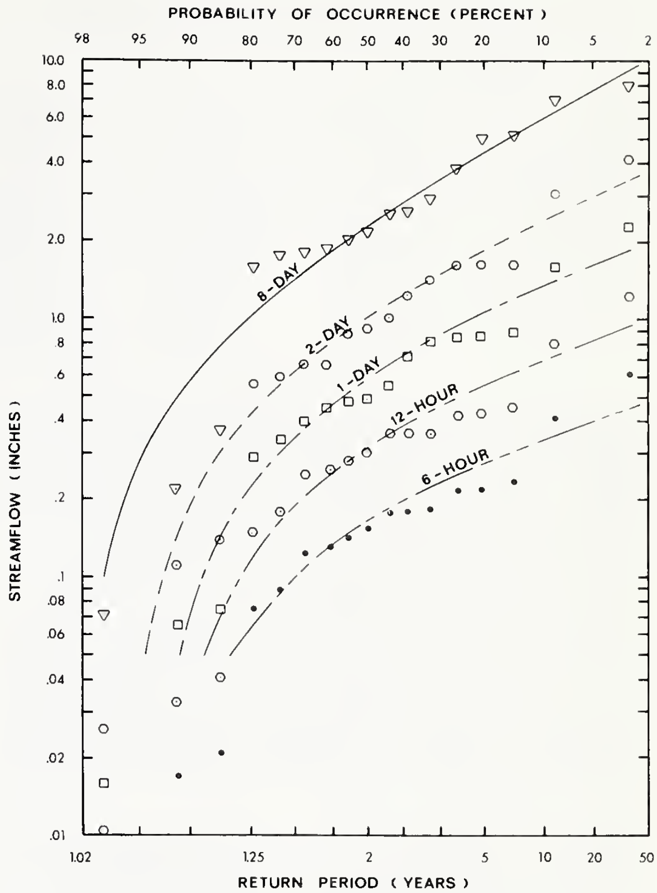

FIGURE 4.20.—Frequency of streamflow volumes for periods of 6 and 12 hours and 1, 2, and 8 days, subwatershed W-3.

maximum volume for all time intervals occurred in the tropical storm of October 1956, and the same general pattern by years exists for streamflow volumes as for annual maximum discharge (tables A-14, A-15, and A-16). After thorough examination and deliberation, it was decided that a volume frequency analysis could be made for the full period of record, irrespective of treatment, without serious bias. Frequency analyses were made for watersheds W-2 and W-3 of annual maximum runoff volumes for periods of 6 and 12 hours and 1, 2, and 8 days. The short record at W-5 did not justify frequency analysis. Data for each time interval, plotted on log-probability paper, are shown in figures 4.19 and 4.20 for W-2 and W-3, respectively. The data are highly skewed, and adjustments for skew were used to develop the frequency curves (*18*). The Hazen method of determining the probability positions of the points (eq. 4.5) is given in section 4.2.2. Although the 1956 storm produced the largest volume of all intervals for both watersheds, the 8-day volume does not indicate a highly infrequent return period. For example, at W-2 the 1956 value plots below the frequency line for the 8-day period and is equivalent to approximately a 25-year return period. At W-3 the 8-day volume for 1956 is only slightly above the frequency curve and indicates approximately a 45-year return period. The storm value differs much more from the frequency line for the time intervals shorter than 8 days. These comparisons indicate that less intense storms may occur on several successive days, resulting in a general initial wetting of the watershed and a continuance of significant runoff over extended periods. This is typical of the summer thunderstorms that occur almost daily.

Since 24-hour runoff is generally used in drainage design, the 1-day values were read from the frequency line in figure 4.19 for return periods of 2.33, 10, and 25 years, the 2.33-year return being equivalent to the "mean annual flood." Values read from the frequency line are 0.63,

Table 4.12.—Runoff volume, in inches, for selected time intervals and return periods for watershed W-2 and subwatershed W-3

Return period (yrs)	Time interval: 6-hour W-2	6-hour W-3	12-hour W-2	12-hour W-3	1-day W-2	1-day W-3	2-day W-2	2-day W-3	8-day W-2	8-day W-3
50	0.46	1.01	1.00	1.91	2.00	3.00	3.75	5.50	10.00	9.10
25	.41	.89	.86	1.63	1.70	2.50	3.10	4.50	8.10	7.50
10	.34	.74	.70	1.33	1.37	2.05	2.45	3.55	6.10	5.90
2.33	.18	.35	.34	.66	.63	1.04	1.09	1.60	2.48	2.77

1.37, and 1.70 inches, respectively. These values are equivalent to mean daily discharge rates of 2,040, 3,630, and 4,510 cubic feet per second, respectively. Comparison of those rates with the rates of 2,040, 3,850, and 4,550 cubic feet per second that were determined by Stephens and Mills (*47*) from frequency analysis of 10-year data shows very good agreement. The 1956 extreme value from the 10-year study resulted in only a slightly higher 25-year estimate than that from the 17-year study. Additional data apparently lowered the frequency line between the 2.33- and 25-year return period. The comparisons indicate that the method of skew adjustment gives relatively reliable results.

Comparison of figures 4.19 and 4.20 shows the effect of size of watershed drainage area and also the apparent long-duration drainage potential caused by the lower topographic position of W-2. The results are shown for comparison in table 4.12. For intervals of up to 2 days, significantly more runoff was produced at W-3 than at W-2. Approximately twice as much runoff occurred at W-3 in 6 hours and about 1.5 times as much occurred at W-3 in 2 days. More runoff occurred at W-2 in the 8-day period, which also allowed ample time for more profile drainage caused by the lower elevation of the gaging station.

4.3.—Ground Water

4.3.1.—Effects of Channelization and Water-Level Control Structures

Objectives of the Upper Taylor Creek watershed study were given in section 1.1.1. Specifically, objective 4 was "to determine the effects of channel improvements and associated water-level controls on storm runoff, water yield, and ground-water levels." This section treats ground water independent of rainfall and streamflow for the network of seven observation wells within the watershed (fig. 1.3) and the two lines of observation wells out from the channel to a distance of 2,000 feet (see section 2.3).

4.3.1.1.—Observation-Well Networks

Data for the seven observation wells in the watershed are summarized in table A-23, which gives mean monthly depth to ground water. Mean monthly values for these wells are shown graphically in figures 4.21–4.27, which also give the ground-surface elevations (G.S.E.). Ground surface at wells 1 and 4 was 65 feet above m.s.l. and was 45 feet at well 2. Ground surface was approximately 35 feet above m.s.l. at the remaining four wells.

Well 1 was near the watershed upper divide (fig. 1.3), and it was located the most remote distance of any well from primary improved channel. Well 2 was lower in elevation and relatively near the channel in subwatershed W-3. Both wells were within W-3. Maximum fluctuations of the two wells, as given by monthly means, were approximately the same, and the patterns throughout the years were about the same. An extended dry period in 1961–62 resulted in minimum levels (maximum depths). A similar dry period in 1967, after channelization in W-3, resulted in about the same depth to ground water below ground surface at both wells. Both wells recovered nearly every year to depths of approximately 0.5 foot below ground surface. Fluctuations of the ground-water levels show that channelization and water-level control structures had negligible effect on the water table. The near proximity of well 2 to the channel apparently had negligible effect. Data from wells 1 and 2 were averaged and are shown graphically in figure 4.28. Since fluctuations of the individual wells were in close agreement, the composite shows little difference from the individuals.

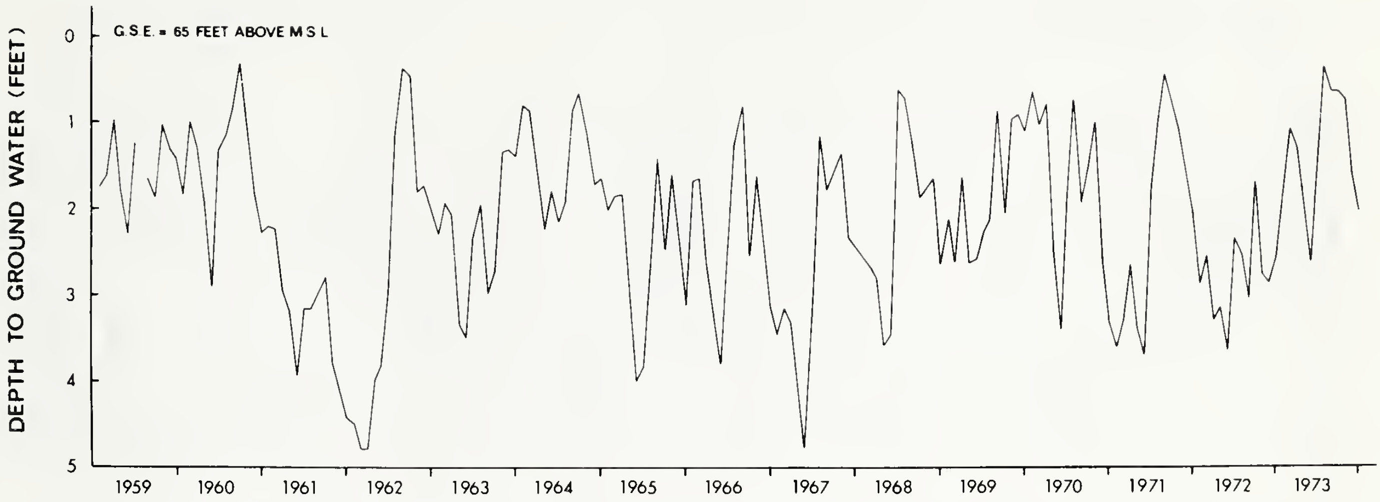

FIGURE 4.21.—Mean monthly depth of ground water, well 1.

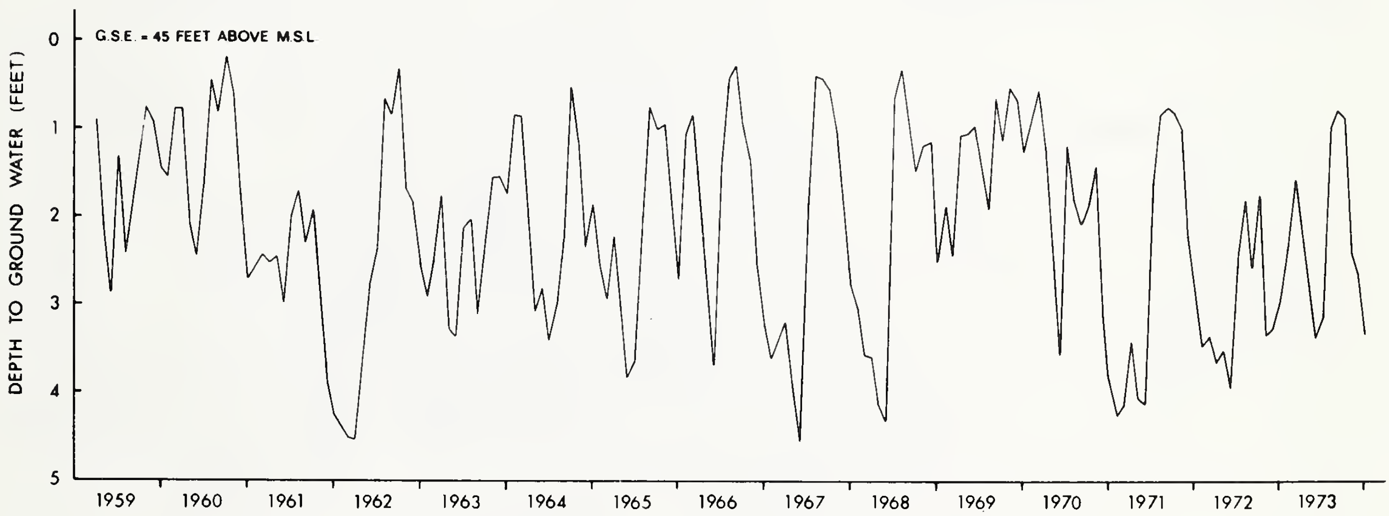

FIGURE 4.22.—Mean monthly depth of ground water, well 2.

Fluctuations of water levels at well 3 closely followed those of wells 1 and 2. The water table at well 3 was never within 1 foot of the ground surface, either before or after channel improvement. The peak levels after channelization returned to about the pretreatment level. The position of well 4 on the landscape is reflected by the rise of the water table to within 6 inches of the ground surface. The difference between extremes was greater than it was at well 1. Well 5 showed greater differences between high and low levels than did any of the other six wells. This well could have been influenced some by the channel, since it was near both the channel and watershed divide. Well 6 was discontinued in September 1968 and was not reestablished until October 1973. Extremes of fluctuations at well 7 were not as great as those for wells 3 through 6. Well 7 was near a citrus area and may have been influenced by irrigation during the dry season. Although this well had water-level peaks after channelization above those before channelization, the 1971 and 1973 peaks were not as near the ground surface, relative to previous years, as were the corresponding peaks at other wells.

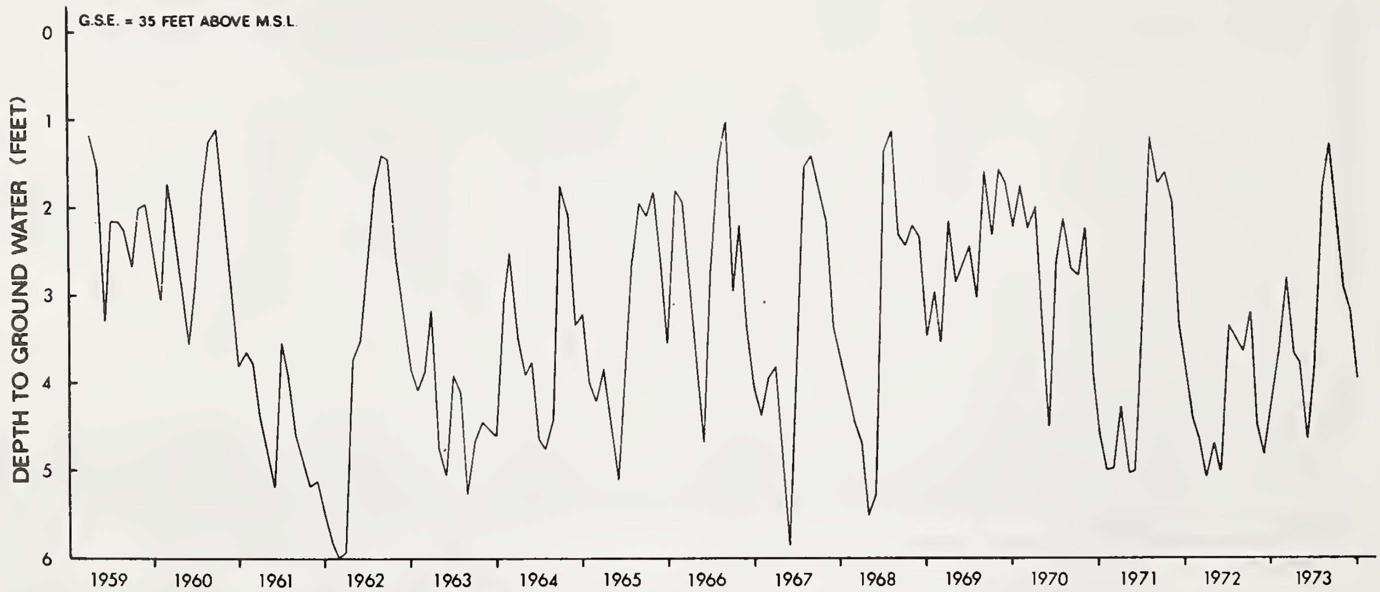

FIGURE 4.23.—Mean monthly depth of ground water, well 3.

FIGURE 4.24.—Mean monthly depth of ground water, well 4.

A composite of all wells is shown in figure 4.29 for watershed W–2. The overall fluctuations show that channel improvement and associated water-level control structures had negligible effect on the ground water of the total study area. The range of fluctuations before and after treatment was about the same. Wells 6 and 7 were averaged and are shown in figure 4.30 for subwatershed W–5. Although streamflow data are not available for W–5 before channelization, ground-water fluctuations were observed. Subwatershed W–5 had a higher drainage density of improved channels than did subwatershed W–3 or watershed W–2 as a whole. Only well 7 was available

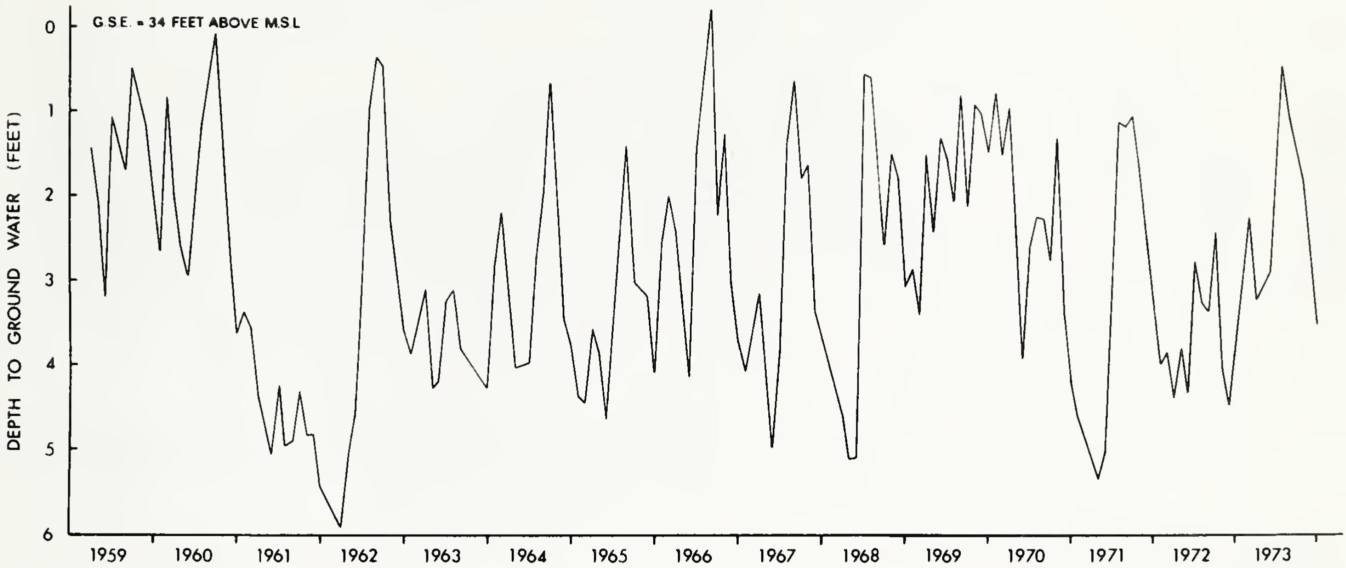

FIGURE 4.25.—Mean monthly depth of ground water, well 5.

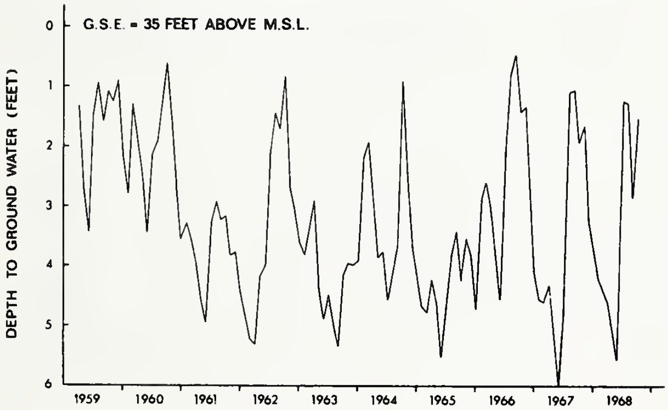

FIGURE 4.26.—Mean monthly depth of ground water, well 6.

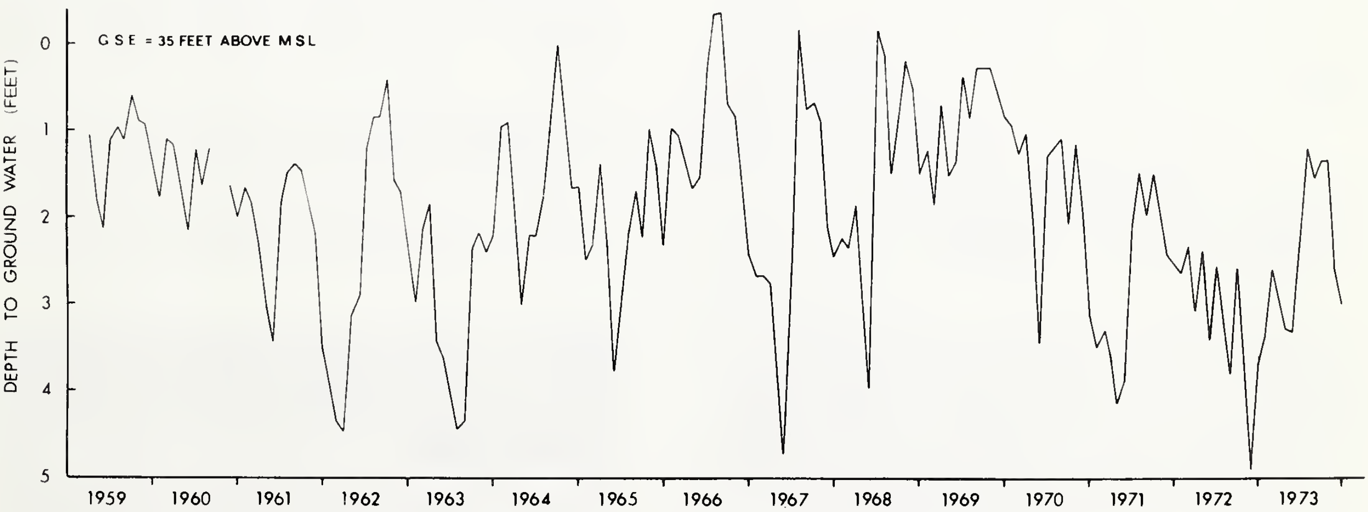

FIGURE 4.27.—Mean monthly depth of ground water, well 7.

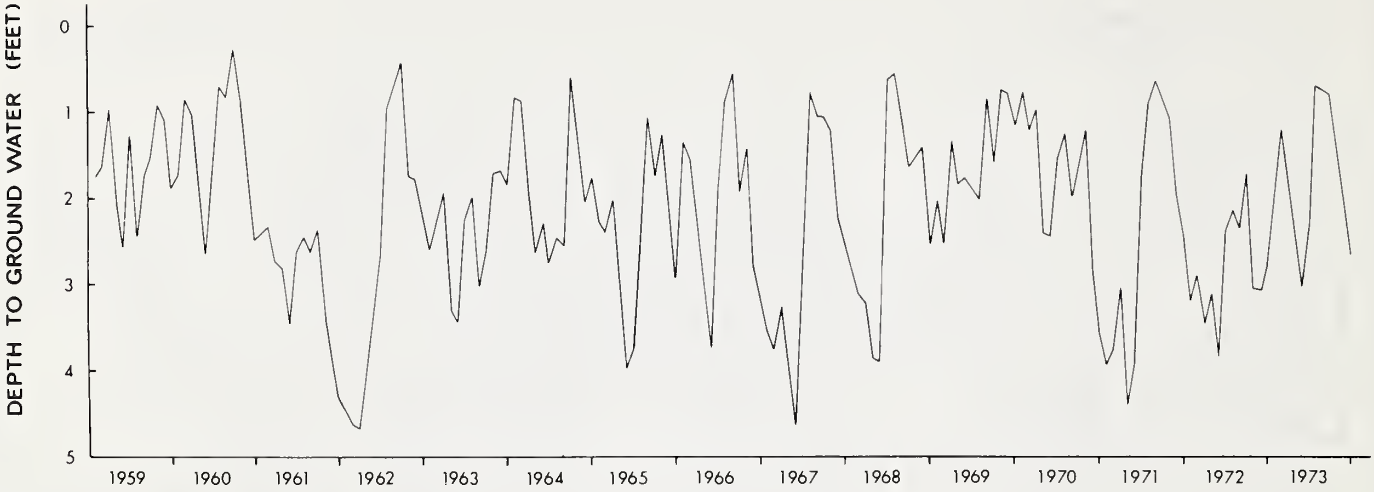

FIGURE 4.28.—Mean monthly depth to ground water, average of wells 1 and 2, subwatershed W-3.

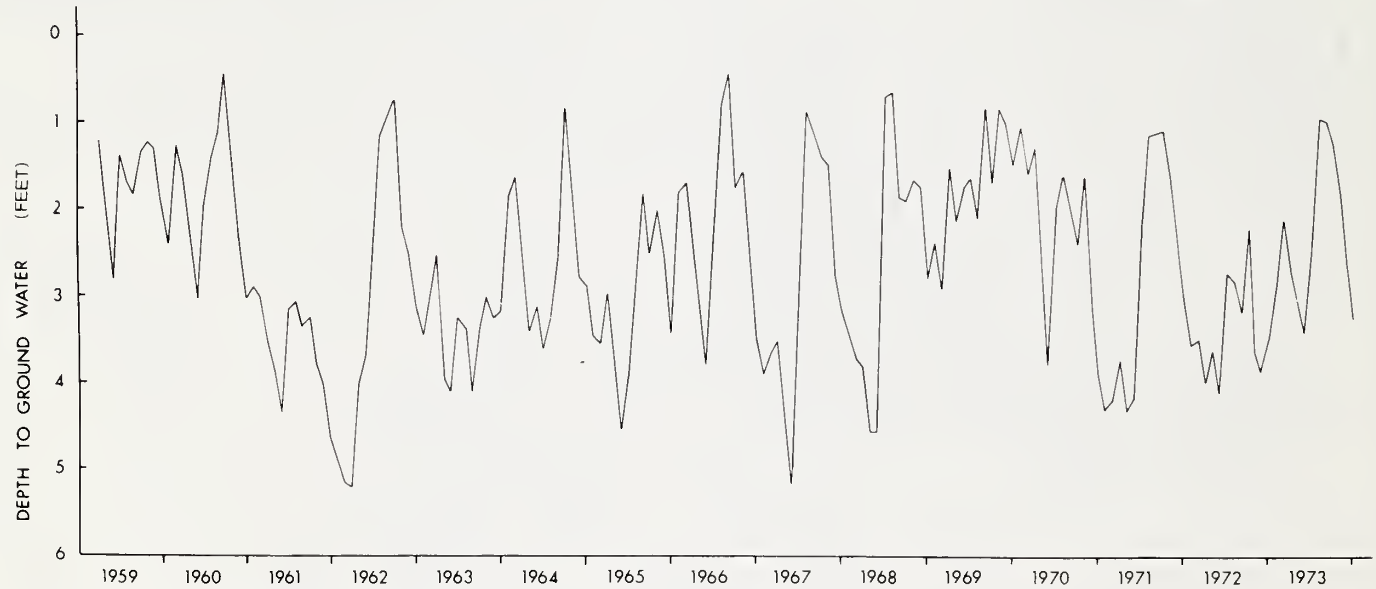

FIGURE 4.29.—Mean monthly depth to ground water, average of wells 1-7, watershed W-2.

for W-5 after 1968; the dashed line in figure 4.30 represents well 7. This does not give a complete picture for the total period. Effects of treatment appear negligible, but again the citrus irrigation may have been a factor in offsetting drainage density effects. Fluctuations of water levels at all wells were in the same order of magnitude, irrespective of the topographic position of the wells. Even with the relatively flat topography of the humid region, the water table represents a subdued replica of the land surface.

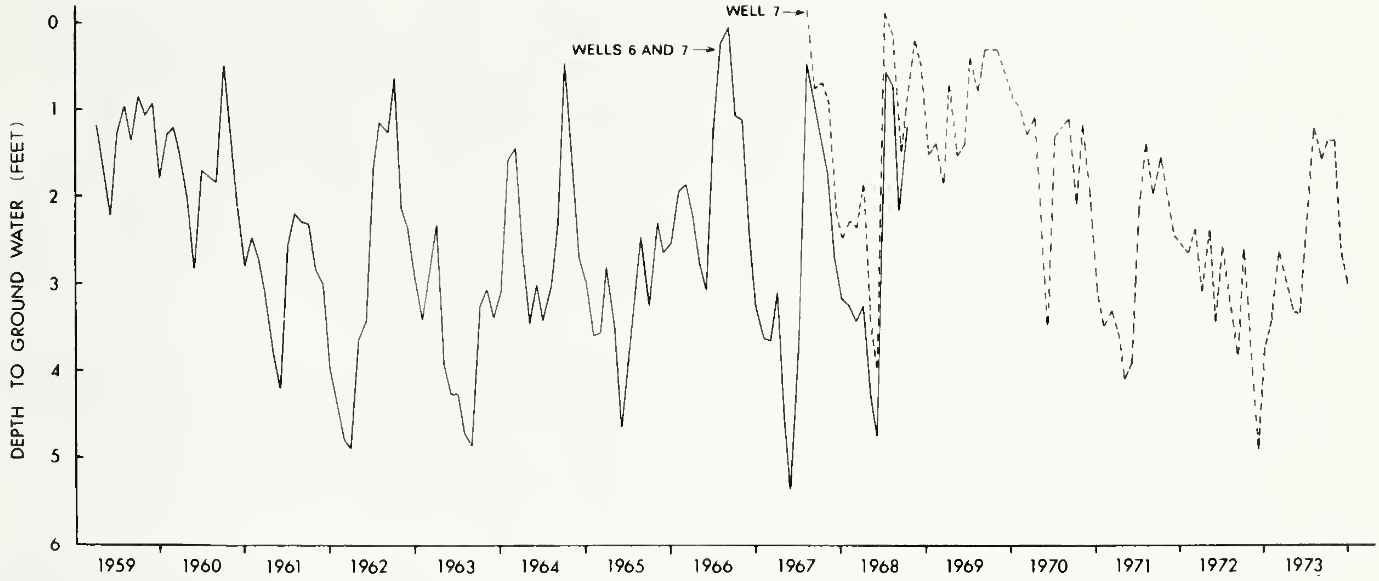

FIGURE 4.30.—Mean monthly depth to ground water, average of wells 6 and 7 (1959–68) and well 7 only (1967–73), subwatershed W-5.

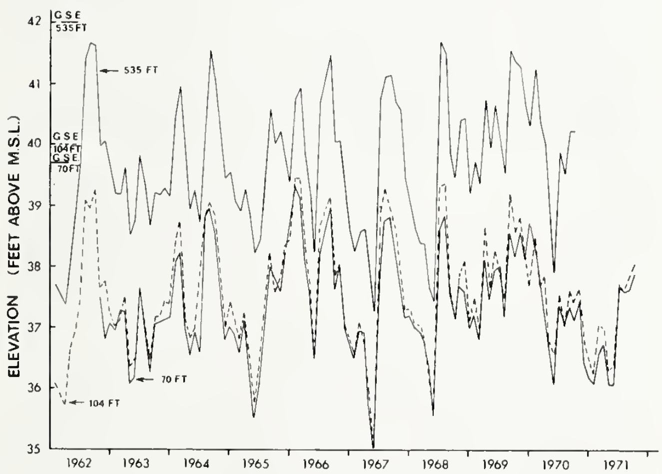

FIGURE 4.31.—Mean monthly ground-water elevations for three selected wells, well-line A.

4.3.1.2.—Ground-Water Profile Adjacent to a Channel Water-table fluctuations as measured weekly on well lines A and B were examined in 1962 to determine the best location for a recorder well to give representation of the respective lines (see section 2.3). The well installed on line A at 70 feet from the channel was instrumented for continuous measurement. Proposed channel alinement and examination of water levels resulted in installation of a recorder on the well at 535 feet from the channel on line B.

Mean monthly ground-water elevations for the recorder well at 70 feet are given in table A–23, and those for the manually measured wells in line A at 104 and 535 feet are given in table A–24. These wells were selected for comparison and are shown graphically in figure 4.31. The curves for the wells at 70 and 104 feet plot very close together, but the curve for the well at 535 feet is significantly higher. Some irregularities exist in the month-to-month changes between wells. This is largely attributable to the monthly values for the wells at 70 and 535 feet, which were determined from four or five measurements per month, whereas those for the well at 104 feet were determined from averaging. However, the relative behavior of the wells is in very close agreement. The peaks at the three wells after channelization in 1964 were approximately the same as those before treatment. The low points, especially in 1967, were lower than the low points before treatment. However, well data reported in section 4.3.1.1 show that the 1967 low was about the same as a low in 1961–62. The low at the 535-foot well in 1967 was approximately 0.1 foot below the low of 1962 (fig. 4.31). At the 104-foot well the 1967 low was approximately 0.7 foot below the 1962 level. Lows for

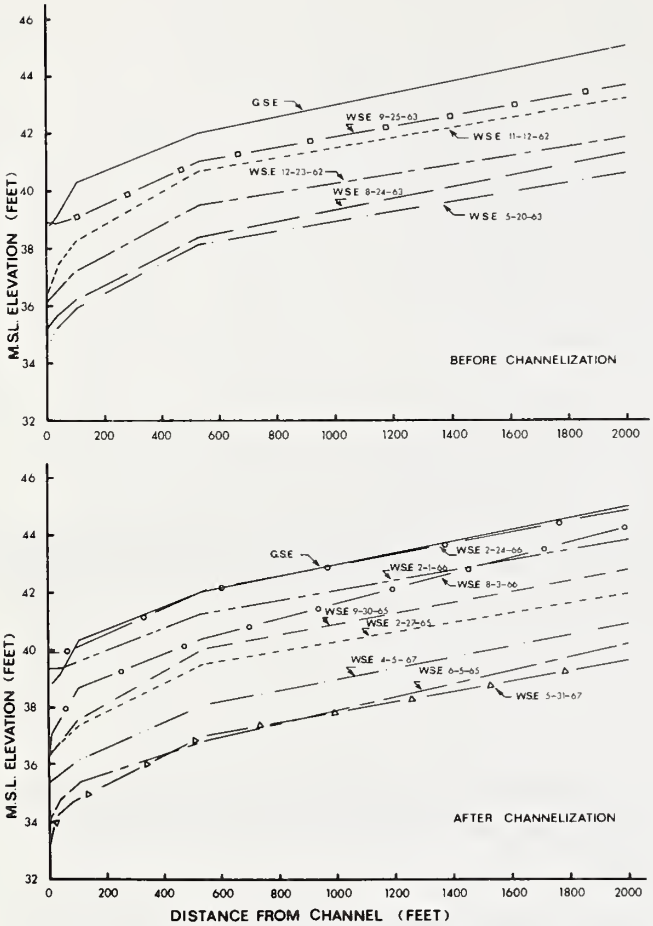

FIGURE 4.32.—Ground-water surface profiles, before and after channelization, well-line A.

the wells at 70 and 104 feet from the channel in 1965, 1968, 1970, and 1971 were below those for 1962. This would indicate that channelization and water-level control structures lowered the water table during the dry periods within 535 feet of the channel. However, the peaks were not affected by channelization. The effects did not show at 535 feet from the channel, but there were no wells between 104 and 535 feet to determine the actual extent of effect.

Dates of manual measurement on line A were selected during wet and dry periods before and after treatment to compare water-surface profiles. The profiles for the pretreatment years are shown in the upper half of figure 4.32. Ground-surface elevations (G.S.E.) at the wells are connected by a solid line. In all cases, both wet and dry conditions, slopes of the water-surface elevations (W.S.E.) between 535 and 2,000 feet are approximately the same as that of the ground surface. However, closer to the channel, the water-surface profile steepens somewhat more than does the ground-surface profile. The profile for 9–25–63 slopes away from the channel to a distance of 38 feet, and at 104 feet the water-surface elevation is relatively high in comparison with profiles of other dates. The profiles represent only one point in time for a transient condition. Obviously, the profile for the data of 9–25–63 represents a period of high channel flow with recharge to bank storage.

The lower half of figure 4.32 shows water-surface profiles for selected dates after channelization. The longer period of record after treatment provided a wider range and more extreme wet and dry conditions. The near-channel reverse slopes for 2–1–66 and 2–24–66 show the effects of recharge to bank storage. The profile of 2–24–66 reveals that during extremely wet periods the ground water was fully recharged to ground surface and that channelization did not preclude such full recharge. Slopes of the profiles within 535 feet of the channel are slightly steeper for the lower water-surface elevations after channelization. This supports the findings based on the data in figure 4.31; i.e., effects of channelization and water-level control structures on ground water are limited to a distance equal to or less than 535 feet from the channel. The seven watershed-network wells discussed in section 4.3.1.1 were all farther than 535 feet from the nearest primary channel, so there is no evidence of channelization overly lowering the water table.

Wells on line B at zero, 10, 38, and 104 feet from the channel were discontinued when channelization reached the line in 1964. Before- and after-treatment comparison within 535 feet of the channel cannot be made for the line. However, mean monthly elevations for the recorder well at 535 feet from the channel are shown in figure 4.33. The recorder well was not installed at this location until October 1962. Since the low water level occurred at other wells in the watershed in early 1962, the mean monthly elevations for the manually measured well at 535 feet are shown in figure 4.33 for the first 9 months for comparative purposes.

During wet periods, the peak water-table elevations were very similar before and after treatment, and the effects of channelization were negligible. However, the low water-table elevations during extended dry periods were significantly lower after channelization, indicating that, as the channel was moved closer to the well at 535 feet in line B, channelization had some effect. The absolute low

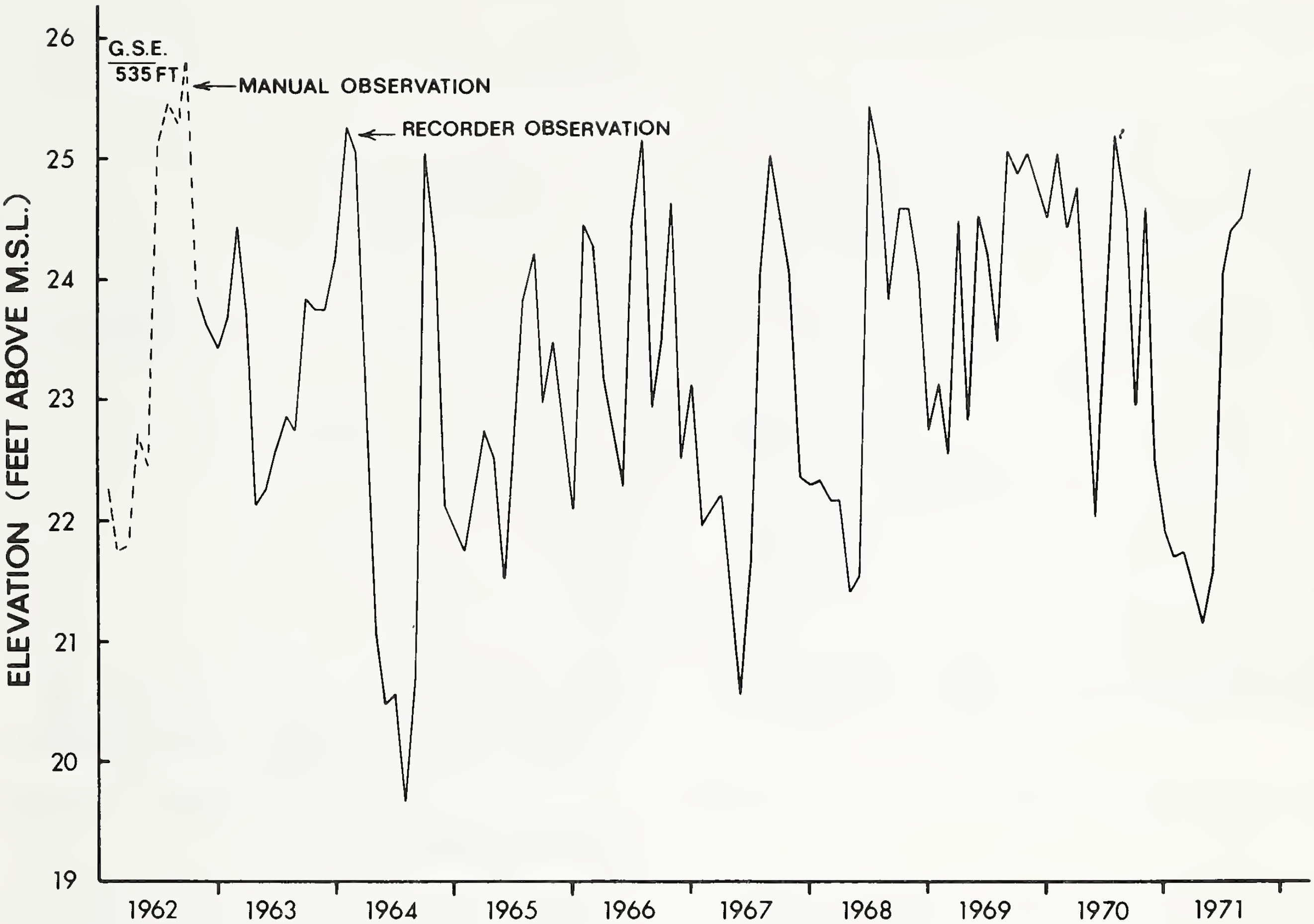

FIGURE 4.33.—Mean monthly ground-water elevations for recorder well, well-line B.

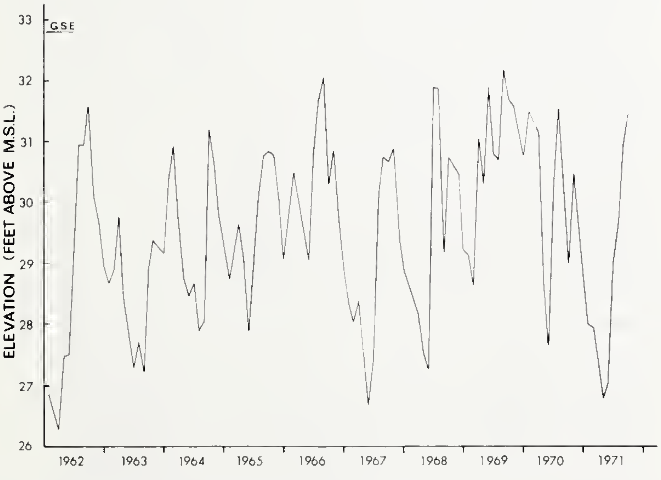

FIGURE 4.34.—Mean monthly ground-water elevations for well at 2,000-foot location, well-line B.

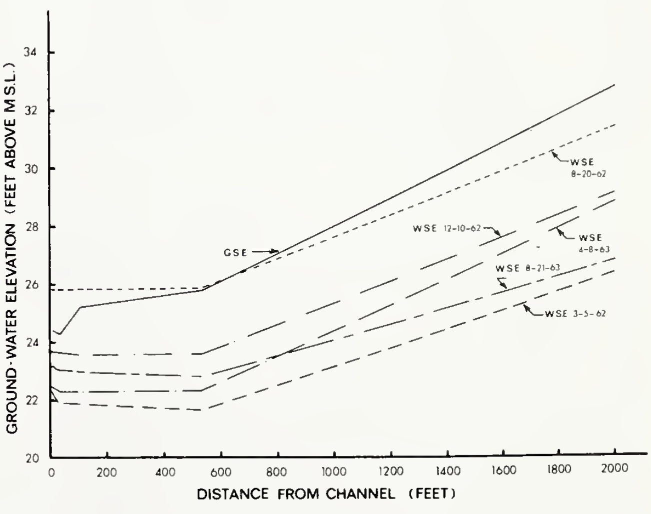

FIGURE 4.35.—Water-surface profiles, before channelization, well-line B.

in 1964 was a direct effect of channelization with downstream water-level control structures open.

Mean monthly ground-water elevations for the well at 2,000 feet in line B (fig. 4.34) do not indicate excessive lowering of the water table during dry periods after channelization, as was indicated for the 535-foot location. Likewise, the extreme low for 1964 at 535 feet was not as low as for other periods at 2,000 feet. In 1967 and 1971, the extreme lows were approximately 0.5 foot higher than that of 1962. Peak elevations at 2,000 feet were obviously not affected by channelization. Water-surface profiles for selected dates at well-line B are shown in figure 4.35 for the before-channelization period only. Since treatment effects cannot be shown at line B, the data only indicate profile characteristics relative to line A (fig. 4.32). The non-uniform slope of the ground surface along well line B makes it impossible to directly compare the two well lines. The water-surface profile, again, is a subdued replica of the ground surface. If wells on line B within 535 feet of the channel had been in operation after channelization, comparisons of profiles and effects of treatment would have been extremely difficult.

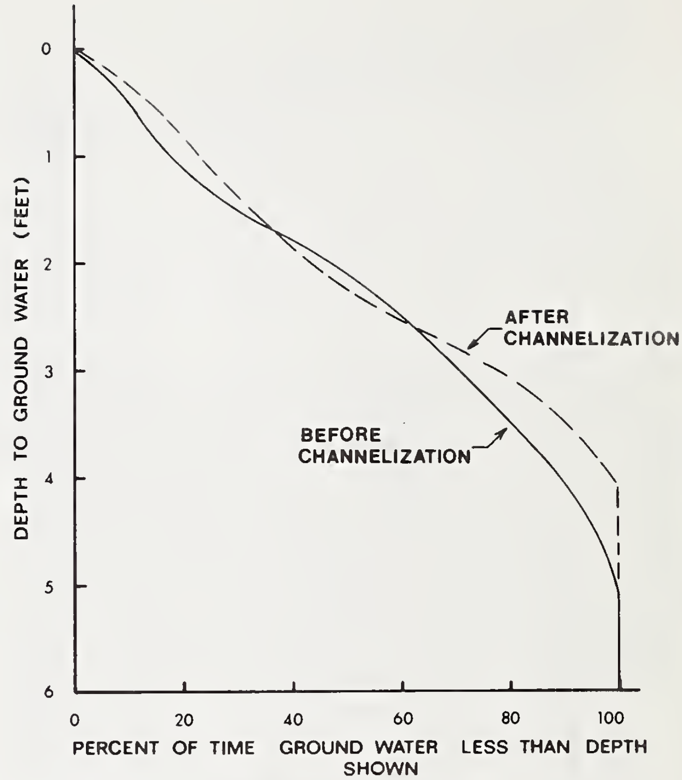

FIGURE 4.36.—Ground-water duration, before and after channelization, well 1.

4.3.2.—Ground-Water Duration

4.3.2.1.—Daily Duration

Ground-water duration curves were developed for watershed network wells 1–5 and 7 for periods before and after channelization and construction of water-level control structures. Well 6 was not in operation during most of the after-treatment period, so treatment effects could not be determined. The respective periods considered were March 1959 through February 1964 and July 1968 through December 1972. Channelization and structural measures were completed near some of the wells before July 1968, but the same periods were used for all wells for comparative purposes.

The ground-water duration curves for before and after treatment are shown in figures 4.36–4.41 for observation wells 1–5 and 7. There was a climatic difference between the two periods, and the before-treatment period was slightly longer than the after-treatment period. The dry season of 1961–62 was the driest on record and produced the lowest water table (sec. 4.3.1.1), which is shown in the ground-water duration curves. There is little difference in the duration curves for wells 1, 2, 4, and 7 (figs. 4.36, 4.37, 4.39, and 4.41). The curves crisscross, an effect that can be caused by climatic difference between the periods. There is less than 0.2-foot difference between treatment periods in ground-water depth at the 50-percent time for wells 1, 2, 4, and 7. Wells 3 and 5 (figs. 4.38 and 4.40) show that after treatment the duration curve is higher, i.e., less depth to ground water for all percentages of time, with the greatest difference near the 50-percent time. The difference is approximately 0.4 foot. Although this difference seems small, it may be significant in evapotranspiration (sec. 5). Wells 3 and 5 were not particularly unique with respect to channel proximity, particularly well 5. Both wells were in the relatively flat midsection of the watershed, which may have been the reason for this lack of uniqueness. Both were far upstream from water-level control structures. Since rainfall was not consistently higher after treatment than before treatment (sec. 3), it must be assumed that installation of water-level control structures had a significant effect on the water table in the flatter areas. This assumption is partially supported by the duration curves at well 1, which was located in the very flat, near-topographic divide in the upper portion of Taylor Creek watershed. The higher water table from 70 to 100 percent of the time (fig. 4.36) could be indicative of water-level control struc-

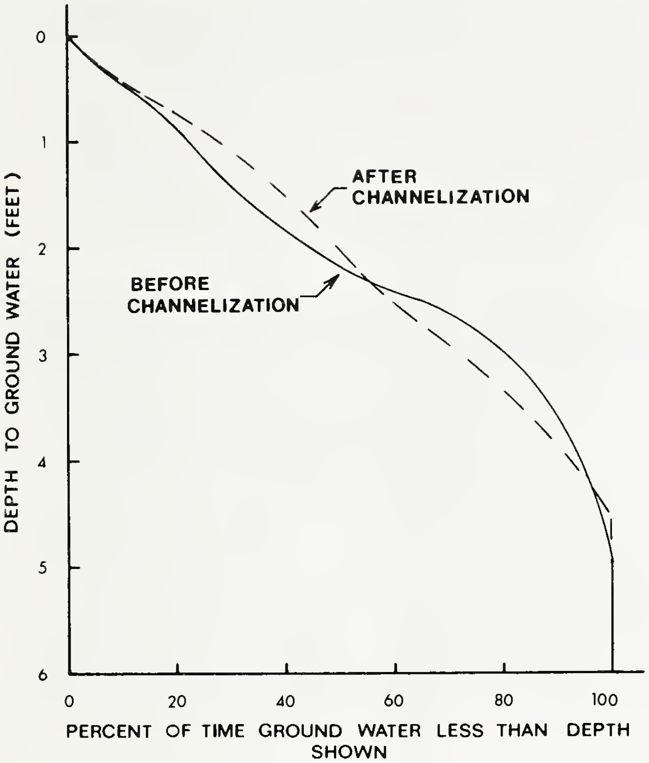

FIGURE 4.37.—Ground-water duration, before and after channelization, well 2.

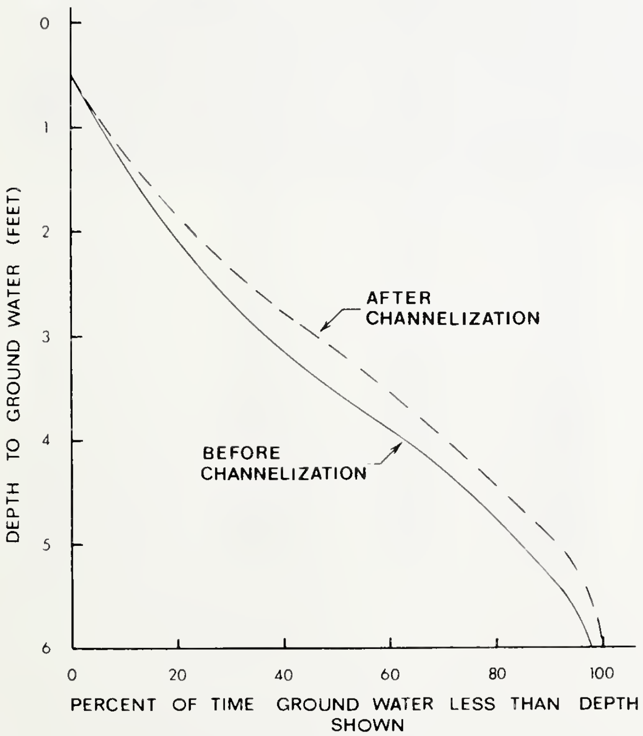

FIGURE 4.38.—Ground-water duration, before and after channelization, well 3.

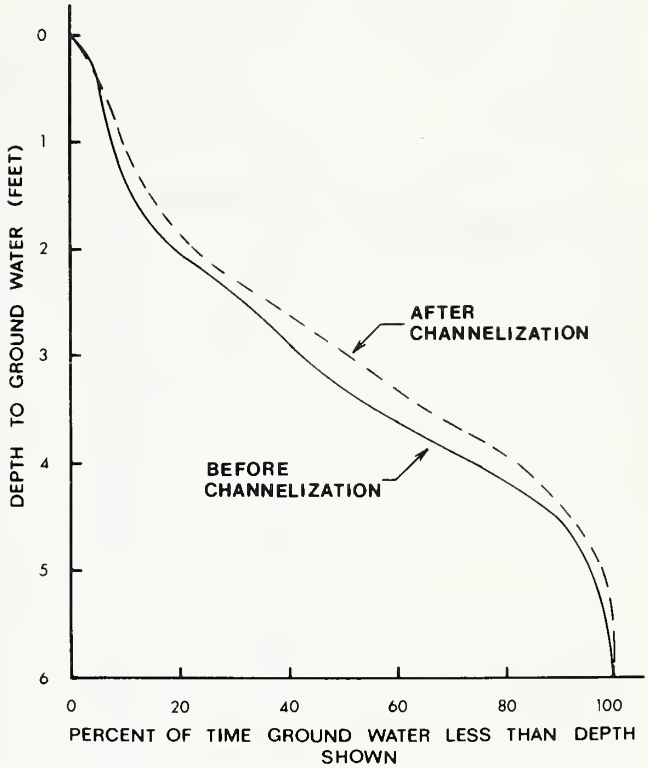

FIGURE 4.39.—Ground-water duration, before and after channelization, well 4.

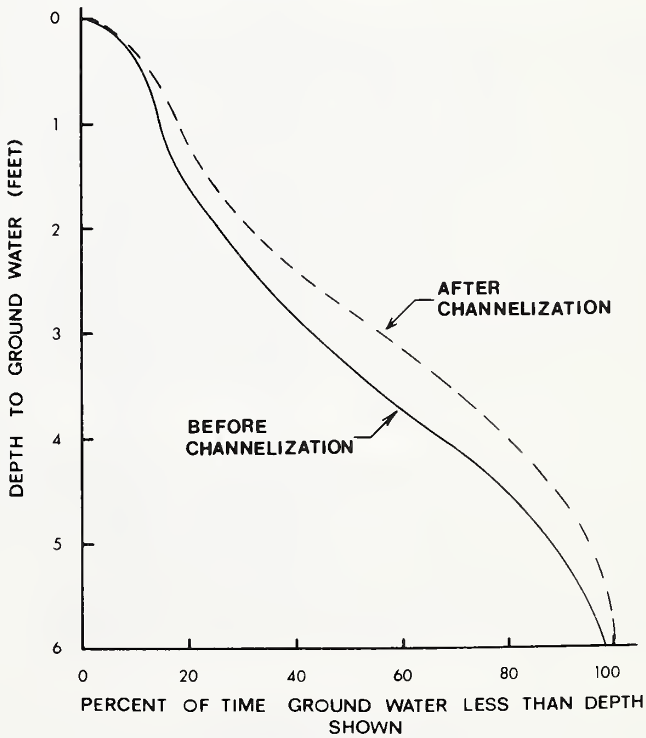

FIGURE 4.40.—Ground-water duration, before and after channelization, well 5.

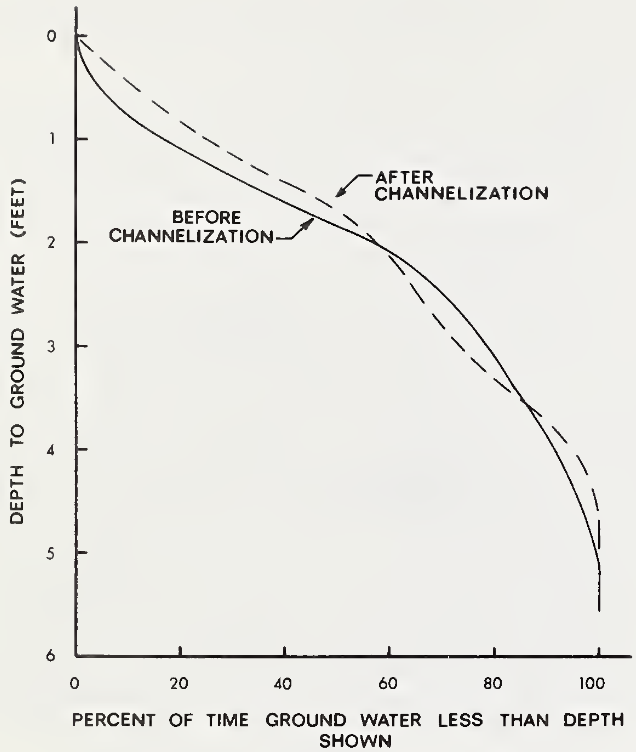

FIGURE 4.41.—Ground-water duration, before and after channelization, well 7.

ture effects. However, it should be pointed out that at well 1 this possible treatment effect was in the 3- to 5-foot range of depth. Duration curves for well 7 (fig. 4.41) show a trend at shallow depths similar to those for wells 3 and 5, but the two curves merge near the 2-foot depth. Well 7 was near a citrus grove and, as discussed in section 4.3.1.1, may have been influenced by irrigation. Estimated citrus rooting depth in the major soils of the watershed is 1.5 to 2 feet (*51*). Irrigation management of citrus during the dry seasons probably results in water application when the water table is at the effective root-zone depth. This could account for the similar duration curves below the 2-foot depth.

Based on the ground-water duration curves, channelization and associated water-level control structures resulted in a water table 0.4 foot higher in the midreaches of Upper Taylor Creek watershed. Lesser effects may have occurred on the flat divide areas. Citrus irrigation negated treatment effects of raising the water table by water-level control structures.

4.3.2.2.—5-, 10-, and 30-Day Durations

Ground-water well data are presented in tabular form in ranked order for the before-treatment period (1960–63), the after-treatment period (1969–72), and the entire record period (1960–73) for comparison of the effect of channel changes on the shallow ground-water aquifer. Duration data were computed for 5-, 10-, and 30-day averaging periods and are presented for four selected averaging periods, near January 1 (period 1), April 1 (period 19), July 1 (period 38), and October 1 (period 56).

Ranked averages (1960–73) for wells 1–5 and 7 are shown in tables 4.13–4.16. Wells were located in two different marine terraces. Wells 1 and 4 were in the upper terrace, and wells 2, 3, 5, and 7 were in the lower terrace. The water table in the upper terrace, beginning January 1, ranged from 60.42 to 64.56 feet above m.s.l. in well 1 and 59.98 to 62.47 feet above m.s.l. for the 5-day averaging period (table 4.13). Ten- and thirty-day averaging periods are also shown. Wells in the lower terrace ranged from a low in well 5 of 28.29 feet above m.s.l. to a high in well 2 of 44.29 feet above m.s.l. for the 5-day averaging period. Periods 19, 38, and 56 had similar ranges. The range variance from wet years to dry years was between 2 and 4 feet over the entire record period.

Tables 4.17–4.20 show the ranked order of the wells for the before-treatment period (1960–63). Tables 4.21–4.24 are for the period after treatment (1969–72). There is no significant difference in the well elevations before and after treatment. The water table was generally higher after treatment and had a smaller range. This indicates that the channel had little if any effect on ground-water storage for the representative selected periods.

Table 4.13.—Well duration for entire record period, beginning January 1, period 1, 1960–73

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	7
			5-day averaging period			
1	64.458	44.288	32.652	62.474	32.052	34.428
2	63.544	44.194	32.134	62.422	31.568	33.852
3	63.484	43.064	31.600	62.394	30.666	33.812
4	63.270	43.014	31.474	61.482	30.488	33.574
5	64.458	44.288	31.600	62.474	30.666	34.428
6	63.544	43.014	31.474	61.194	30.298	33.222
7	62.486	42.292	31.252	61.452	30.294	33.202
8	62.476	42.180	30.914	61.092	29.968	33.192
9	62.414	42.360	31.348	61.482	30.294	33.192
10	62.214	42.184	31.234	61.052	30.488	33.574
11	63.270	43.064	32.134	62.394	31.568	33.852
12	61.676	41.566	30.672	60.742	29.570	31.868
13	62.594	41.976	30.672	61.194	30.298	33.222
14	62.486	41.988	30.864	61.092	30.340	31.674
			10-day averaging period			
1	64.388	44.261	32.929	63.053	32.671	34.409
2	63.950	44.011	32.454	62.535	31.740	34.143
3	63.379	43.642	32.118	62.305	30.933	33.767
4	63.361	43.017	31.737	62.281	30.759	33.730
5	64.388	44.261	31.702	62.535	30.759	34.409
6	63.361	42.909	31.392	61.397	30.212	33.241
7	62.720	43.017	32.118	62.281	30.212	33.719
8	62.571	42.142	30.887	61.054	30.133	33.069
9	62.571	42.301	31.225	61.397	30.133	33.069
10	62.707	42.561	31.737	61.438	30.933	33.767
11	63.950	43.642	32.929	63.053	32.671	34.143
12	61.661	41.538	30.616	60.701	29.672	31.890
13	62.475	41.874	30.616	61.153	30.183	33.106
14	62.372	41.888	30.766	61.036	30.234	31.592
			30-day averaging period			
1	64.285	44.196	33.223	63.518	33.105	34.311
2	64.235	44.070	33.004	62.992	31.177	34.310
3	63.164	43.774	32.007	62.578	31.073	34.161
4	63.059	43.453	31.936	61.998	30.998	33.910
5	64.235	44.196	31.890	62.578	30.998	34.311
6	63.052	42.553	31.333	61.432	30.587	33.469
7	63.164	43.774	33.004	62.992	31.073	34.161
8	62.848	42.439	31.087	61.198	29.965	32.815
9	62.749	42.075	30.940	61.198	29.862	33.005
10	62.848	43.048	32.007	61.751	30.985	33.910
11	64.225	44.070	33.223	63.518	33.105	34.310
12	61.539	41.414	30.554	60.575	29.510	31.832
13	62.196	41.607	30.554	60.957	29.925	32.703
14	63.059	42.439	31.113	61.350	30.587	31.832

Table 4.14.—Well duration for entire record period, beginning April 1, period 19, 1960–73

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	7
			5-day averaging period			
1	64.384	44.370	33.212	63.734	33.106	34.610
2	64.176	44.270	32.636	62.900	32.048	34.302
3	63.294	43.526	32.152	62.832	31.198	34.072
4	63.232	43.000	31.694	62.482	30.880	33.924
5	63.094	42.686	31.608	61.800	30.810	33.734
6	62.870	42.506	31.238	61.492	30.880	34.072
7	62.404	42.368	31.174	61.800	30.810	33.734
8	62.294	42.326	30.920	61.076	30.114	32.664
9	62.150	42.226	30.832	60.970	29.864	32.724
10	63.232	44.270	32.636	62.832	32.048	34.302
11	64.384	44.370	33.212	63.734	33.106	34.610
12	62.150	41.268	30.450	61.076	29.028	31.964
13	61.614	41.280	29.872	60.492	29.628	32.288
14	64.176	43.000	31.694	62.482	30.458	32.664
			10-day averaging period			
1	63.858	44.321	32.894	63.188	32.642	34.264
2	63.767	44.040	32.816	63.185	32.029	34.230
3	63.309	43.365	32.236	63.155	31.280	33.921
4	63.194	42.771	31.785	62.297	31.090	33.827
5	63.007	42.677	31.535	61.940	30.657	33.818
6	62.638	42.472	31.406	61.403	30.657	33.827
7	62.248	42.472	31.785	61.940	31.090	33.921
8	62.171	42.264	30.847	61.032	30.062	32.509
9	62.159	42.135	30.716	60.919	30.023	32.566
10	63.194	44.321	32.894	63.188	32.029	34.230
11	63.858	44.040	32.816	63.155	32.642	34.264
12	62.159	41.283	30.385	61.032	28.977	32.120
13	62.027	41.648	30.330	60.885	30.146	32.995
14	63.767	42.771	31.535	62.297	30.568	32.442
			30-day averaging period			
1	63.160	44.023	32.246	62.625	31.444	33.847
2	63.131	42.960	32.156	62.374	31.375	33.648
3	62.792	42.943	31.898	62.332	31.260	33.588
4	62.703	42.553	31.399	61.972	30.769	33.401
5	62.703	42.477	31.236	61.639	30.711	33.059
6	62.052	42.301	31.215	61.172	30.063	33.059
7	61.865	42.301	31.399	61.639	30.711	33.648
8	61.829	41.959	30.485	60.791	29.823	32.136
9	61.711	41.755	30.311	60.789	29.723	32.132
10	62.489	44.023	32.246	62.625	31.375	33.847
11	62.792	42.960	31.898	62.332	31.444	33.401
12	61.703	41.085	30.088	60.789	28.799	31.887
13	61.865	41.482	30.289	60.745	30.032	32.840
14	63.131	42.477	31.236	61.972	30.769	32.132

Table 4.15.—Well duration for entire record period, beginning July 1, period 38, 1960–73

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	7
	5-day averaging period					
1	64.692	44.796	34.232	64.870	33.872	35.772
2	64.516	44.766	33.920	63.532	33.436	35.586
3	64.408	44.570	33.842	63.686	33.334	35.198
4	64.288	44.476	33.290	63.460	32.842	34.716
5	63.918	44.226	32.896	63.296	32.754	34.300
6	63.894	43.908	32.878	63.176	32.214	34.254
7	63.100	44.476	32.896	62.964	32.754	35.586
8	64.288	44.796	33.920	64.532	33.436	35.198
9	64.692	44.766	34.232	64.870	33.872	35.772
10	62.666	43.096	31.852	62.534	31.576	34.716
11	64.408	43.336	32.258	63.176	31.180	34.056
12	63.894	43.908	33.842	63.460	32.010	34.234
13	62.148	42.210	31.422	61.586	30.696	32.394
14	64.516	42.602	32.282	63.296	33.334	33.995
	10-day averaging period					
1	64.714	44.794	34.291	64.929	33.913	35.809
2	64.515	44.740	33.987	64.594	33.502	35.231
3	64.488	44.461	33.862	64.250	32.991	35.185
4	64.289	44.431	33.407	64.039	32.982	34.828
5	64.248	44.415	33.044	63.400	32.909	34.540
6	63.927	44.139	32.947	63.377	32.790	34.234
7	63.648	44.461	33.044	63.097	32.909	35.185
8	64.289	44.740	33.862	64.594	32.982	35.231
9	64.714	44.794	34.291	64.929	33.913	35.809
10	62.712	42.879	31.664	62.364	31.352	34.828
11	64.515	43.209	32.612	63.400	31.321	34.056
12	64.248	44.139	33.987	64.039	32.331	34.234
13	62.161	42.759	31.583	61.543	30.736	32.394
14	64.488	42.951	32.380	63.377	33.502	33.995
	30-day averaging period					
1	64.604	44.689	33.870	64.435	33.353	35.569
2	64.233	44.592	33.788	63.895	33.219	35.410
3	64.224	44.582	33.490	63.891	33.146	35.110
4	64.094	44.533	33.380	63.657	32.781	34.473
5	64.006	44.223	33.208	63.616	32.734	34.250
6	63.835	44.179	33.198	63.540	32.722	34.108
7	63.792	44.592	33.490	63.657	33.146	35.569
8	63.885	44.588	33.380	63.891	32.462	35.410
9	64.224	44.689	33.870	64.435	33.219	35.110
10	63.048	43.199	31.969	62.261	31.749	34.473
11	64.233	43.199	32.898	63.231	31.611	34.108
12	64.006	44.179	33.788	63.540	32.734	33.764
13	62.488	43.232	31.494	62.180	30.608	32.224
14	64.604	44.000	33.198	63.895	33.353	34.043

Table 4.16.—Well duration for entire record period, beginning October 1, period 56, 1960–73

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	7
			5-day averaging period			
1	64.644	44.720	34.030	64.002	33.756	35.132
2	64.564	44.590	33.710	63.580	33.278	35.002
3	64.514	44.422	34.030	63.436	33.756	34.796
4	64.132	44.352	33.520	63.264	33.092	34.702
5	64.108	44.156	33.414	63.112	32.478	34.670
6	63.988	44.120	33.520	63.112	32.170	34.796
7	63.952	43.986	33.302	62.688	31.886	34.292
8	64.108	44.422	33.374	63.580	33.278	35.002
9	63.546	43.748	32.338	62.330	31.464	34.702
10	63.892	44.720	33.710	64.002	33.192	35.132
11	64.644	44.120	33.302	62.048	32.478	34.080
12	62.340	42.650	31.694	62.330	30.854	33.350
13	62.254	42.544	30.782	61.258	30.178	32.652
14	64.514	43.078	32.114	63.264	31.886	34.104
			10-day averaging period			
1	64.644	44.769	33.775	64.298	33.313	35.146
2	64.578	44.554	33.741	63.943	33.310	34.864
3	64.231	44.389	33.489	63.540	33.274	34.588
4	64.144	44.234	33.465	63.106	32.985	34.542
5	64.065	44.219	33.463	63.043	32.846	34.406
6	63.923	44.109	33.465	63.043	31.885	34.542
7	63.850	44.080	33.413	62.505	31.861	34.305
8	64.065	44.389	33.463	63.943	33.313	34.864
9	63.591	43.461	32.209	62.382	31.263	34.406
10	64.144	44.769	33.741	64.298	33.310	35.146
11	64.644	44.234	33.489	62.382	32.985	34.203
12	62.521	43.055	32.163	62.407	30.963	33.303
13	62.697	42.549	30.846	61.786	30.165	32.670
14	64.231	42.751	31.901	63.106	31.683	33.890
			30-day averaging period			
1	64.308	44.468	33.357	63.989	32.846	35.052
2	64.030	44.381	33.130	63.646	32.653	34.907
3	63.960	44.073	33.084	63.377	32.598	34.405
4	63.953	43.985	33.008	62.887	32.377	34.367
5	63.888	43.938	32.946	62.869	32.338	34.308
6	63.817	44.073	33.130	62.818	32.217	34.262
7	63.632	43.800	32.816	62.681	32.598	34.405
8	63.616	43.938	32.833	63.377	32.217	34.367
9	63.384	43.800	32.802	62.227	32.338	35.052
10	63.953	44.468	33.357	63.989	32.846	34.907
11	64.030	43.648	32.816	62.227	32.653	34.060
12	63.817	43.985	33.008	62.887	32.149	33.262
13	62.319	42.178	30.557	61.457	29.856	33.063
14	64.308	42.699	32.097	63.646	32.104	33.973

Table 4.17.—Well duration for period before channelization, beginning January 1, period 1, 1960–63

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	6	7
				5-day averaging period			
1	63.484	44.194	32.652	62.422	32.052	32.684	33.812
2	62.812	42.180	30.914	61.092	29.968	31.238	33.244
3	62.476	42.076	30.904	60.920	29.932	31.180	32.466
4	62.812	42.180	30.904	60.920	29.968	31.180	32.466
				10-day averaging period			
1	63.379	44.011	32.454	62.305	31.740	32.538	33.730
2	62.821	42.142	30.887	61.054	29.933	31.202	33.241
3	62.518	42.048	30.882	60.882	29.916	31.149	32.457
4	62.821	42.142	30.887	60.882	29.933	31.149	32.457
				30-day averaging period			
1	63.047	43.453	31.936	61.998	31.177	32.179	33.581
2	62.905	42.447	31.333	61.432	30.461	31.706	33.581
3	62.749	42.075	30.929	60.823	29.965	31.182	32.262
4	62.749	42.075	30.929	60.823	29.965	31.182	32.262

Table 4.18.—Well duration for period before channelization, beginning April 1, period 19, 1960–63

Rank	Ground-water elevations (ft above m.s.l.) for well — 1	2	3	4	5	6	7
				5-day averaging period			
1	63.294	43.526	32.152	62.900	31.198	32.940	33.924
2	62.404	42.686	31.238	61.154	29.864	31.154	32.750
3	62.294	42.226	31.238	60.918	29.328	30.714	32.612
4	62.404	42.226	30.832	61.154	29.864	31.154	32.750
				10-day averaging period			
1	63.309	43.365	32.236	63.185	31.280	33.034	33.818
2	62.248	42.677	31.406	61.098	29.797	31.054	32.509
3	62.171	42.135	31.406	60.919	29.295	30.781	32.507
4	62.171	42.135	30.716	61.098	29.797	31.054	32.509
				30-day averaging period			
1	63.160	42.943	32.156	62.374	31.260	32.554	33.588
2	61.829	42.553	31.215	60.833	29.579	30.827	32.238
3	61.711	41.755	31.215	60.791	29.151	30.682	32.136
4	61.711	41.755	30.311	60.833	29.579	30.470	31.887

Table 4.19.—Well duration for period before channelization, beginning July 1, period 38, 1960–63

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
	5-day averaging period						
1	63.918	44.570	33.290	63.686	32.842	33.650	34.300
2	62.722	44.226	32.878	62.828	32.214	32.694	33.774
3	62.722	44.226	32.878	63.686	32.214	33.650	34.300
4	62.502	42.926	31.438	62.076	30.894	30.162	30.710
	10-day averaging period						
1	63.927	44.431	33.407	64.250	32.991	34.034	34.540
2	63.648	44.415	32.947	62.710	32.790	32.853	33.795
3	63.648	44.431	33.407	64.250	32.991	34.034	34.540
4	62.712	42.689	31.229	62.048	30.657	32.068	30.652
	30-day averaging period						
1	64.094	44.533	33.208	63.616	32.781	33.358	34.250
2	63.792	44.223	33.074	63.375	32.722	33.256	33.710
3	63.792	44.223	33.208	63.316	32.781	33.358	34.250
4	63.048	42.937	30.738	61.891	30.617	29.963	30.766

Table 4.20.—Well duration for period before channelization, beginning October 1, period 56, 1960–63

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
	5-day averaging period						
1	64.564	44.590	34.030	63.436	33.756	33.892	34.670
2	64.132	44.352	33.558	62.688	33.092	33.174	34.292
3	63.952	44.352	34.030	62.688	33.756	33.174	34.292
4	64.132	43.616	31.130	62.348	30.442	31.506	33.720
	10-day averaging period						
1	64.578	44.554	33.775	63.540	33.274	33.973	34.588
2	63.850	44.219	33.461	62.505	32.846	32.882	34.133
3	63.614	44.219	33.461	62.505	32.846	32.882	34.133
4	63.850	43.351	30.937	62.186	30.271	31.346	33.525
	30-day averaging period						
1	63.960	44.381	33.084	62.869	32.377	33.275	34.148
2	63.632	43.297	32.411	62.003	31.573	32.293	33.661
3	63.157	43.297	32.411	62.003	31.573	32.293	33.661
4	63.632	42.226	30.534	61.811	29.831	31.016	33.063

Table 4.21.—Well duration for period after channelization, beginning January 1, period 1, 1969–72

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
				5-day averaging period			
1	64.030	43.644	32.978	63.182	32.784	....	34.140
2	64.030	43.644	32.978	63.182	32.784	....	34.140
3	62.432	41.838	30.558	61.148	30.144	....	33.088
4	62.432	41.838	30.558	61.148	30.144	....	33.088
				10-day averaging period			
1	64.362	44.040	33.382	63.397	33.322	....	34.346
2	64.362	44.040	33.382	63.397	33.322	....	34.346
3	62.344	41.760	30.561	61.100	30.066	....	32.953
4	62.344	41.760	30.561	61.100	30.066	....	32.953
				30-day averaging period			
1	64.350	44.134	33.260	63.559	33.120	....	34.319
2	64.350	44.134	33.060	63.559	33.120	....	34.319
3	62.121	41.533	30.599	60.900	29.849	....	32.610
4	62.121	41.533	30.599	60.900	29.849	....	32.610

Table 4.22.—Well duration for period after channelization, beginning April 1, period 19, 1969–72

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
				5-day averaging period			
1	63.750	44.312	33.072	63.446	32.486	....	34.206
2	63.750	44.000	32.628	62.804	32.486	....	34.134
3	62.446	41.936	30.664	61.182	30.606	....	33.624
4	62.446	41.936	30.664	61.182	30.606	....	33.624
				10-day averaging period			
1	63.288	44.235	32.849	63.140	31.997	....	34.119
2	63.288	43.649	32.383	62.595	31.997	....	33.907
3	62.316	41.878	30.677	61.162	30.528	....	33.540
4	62.316	41.878	30.677	61.162	30.528	....	33.540
				30-day averaging period			
1	62.504	43.964	32.132	62.534	31.389	....	33.717
2	62.504	42.680	31.622	62.048	31.129	....	33.138
3	61.867	41.492	30.309	60.743	30.068	....	32.880
4	61.867	41.492	30.309	60.743	30.068	....	32.880

Table 4.23.—Well duration for period after channelization, beginning July 1, period 38, 1969–72

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
				5-day averaging period			
1	64.560	44.086	34.000	64.304	31.866	....	35.270
2	64.560	43.128	33.006	63.608	31.600	....	34.186
3	64.366	44.086	34.000	64.304	31.866	....	34.186
4	61.992	42.576	31.562	61.470	30.680	....	32.230
				10-day averaging period			
1	64.577	44.180	33.845	64.325	32.535	....	34.859
2	64.577	43.241	32.858	63.469	31.399	....	34.211
3	64.265	44.180	33.845	64.325	32.535	....	34.211
4	62.206	43.241	31.669	61.532	30.699	....	32.521
				30-day averaging period			
1	64.141	44.203	33.718	63.596	32.769	....	34.473
2	64.141	43.212	32.983	63.183	31.748	....	34.117
3	64.035	44.203	33.718	63.596	32.769	....	33.654
4	62.430	43.212	31.412	62.192	30.521	....	32.104

Table 4.24.—Well duration for period after channelization, beginning October 1, period 56, 1969–72

Rank	Ground-water elevations (ft above m.s.l.) for well —						
	1	2	3	4	5	6	7
				5-day averaging period			
1	64.646	44.868	34.132	64.878	33.870	....	35.504
2	64.628	44.328	33.556	62.402	33.474	....	34.232
3	62.840	42.778	31.996	62.224	30.772	....	32.440
4	62.840	42.086	30.844	61.766	30.184	....	31.908
				10-day averaging period			
1	64.616	44.751	33.645	64.335	33.538	....	35.163
2	64.616	44.332	33.645	62.698	33.538	....	34.245
3	63.165	43.675	32.850	62.698	31.618	....	32.985
4	62.776	42.008	30.794	61.666	30.077	....	31.753
				30-day averaging period			
1	64.088	44.480	33.460	64.149	32.978	....	35.028
2	64.019	44.118	33.071	62.915	32.500	....	34.089
3	64.019	44.118	33.071	62.915	32.231	....	33.369
4	62.256	41.661	30.486	61.368	29.766	....	31.585

4.3.3.—Maximum and Minimum 5-day Ground-Water Elevations

Ground-water well data, showing the maximum and minimum values for the selected time-interval periods (before and after treatment and the entire record period), are presented in this section. The 5-day-duration averaging periods selected for presentation are January 1 (period 1), April 1 (period 19), July 1 (period 38), and October 1 (period 56). Figures 4.42 and 4.43, for the entire record period (1960–73), show less than 1 foot of variation for all wells, and there is little variation between periods. Figures 4.44–4.46, for the before-treatment period, show a somewhat smaller range than the ranges for the entire record period, but variations were less than 1 foot. The plots in figures 4.47 and 4.48 for the after-treatment period are not significantly different from the other two periods. The maximum and minimum values, as well as the ranked-order well data, indicate little if any difference in the three selected time periods (before and after treatment and the entire record period).

4.3.4.—Moving Averages

Graphs were plotted for the seven ground-water observation wells, showing medians for 5-, 10-, and 30-day averaging periods. Before- and after-treatment time periods were plotted as well as the entire 14-year record

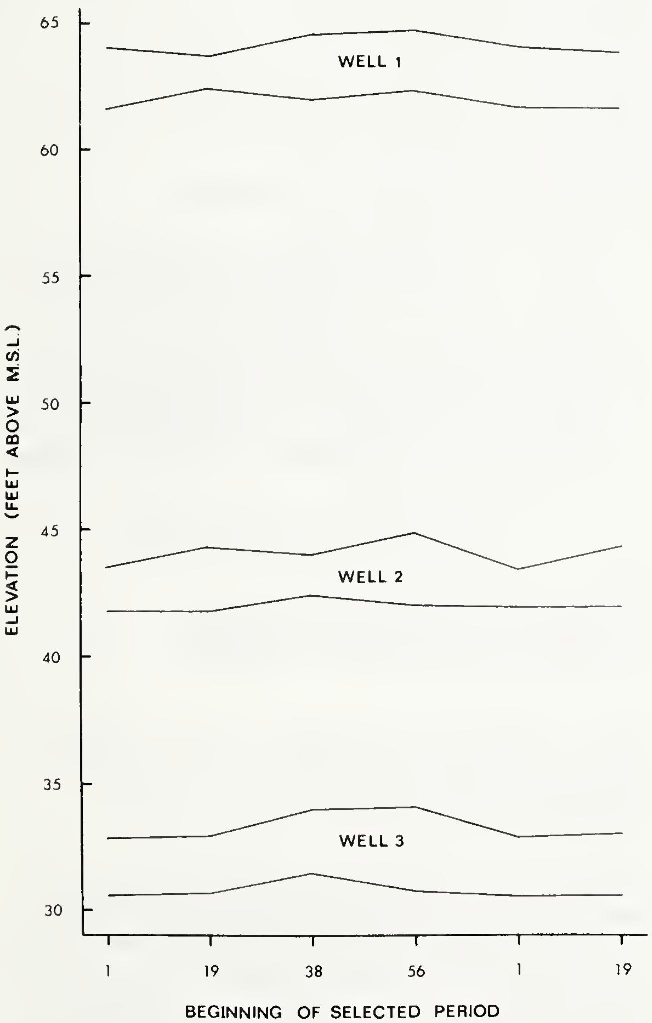

FIGURE 4.42.—Annual cycle of ground-water elevation, 5-day averages for entire record period, wells 1, 2, and 3, 1960–73.

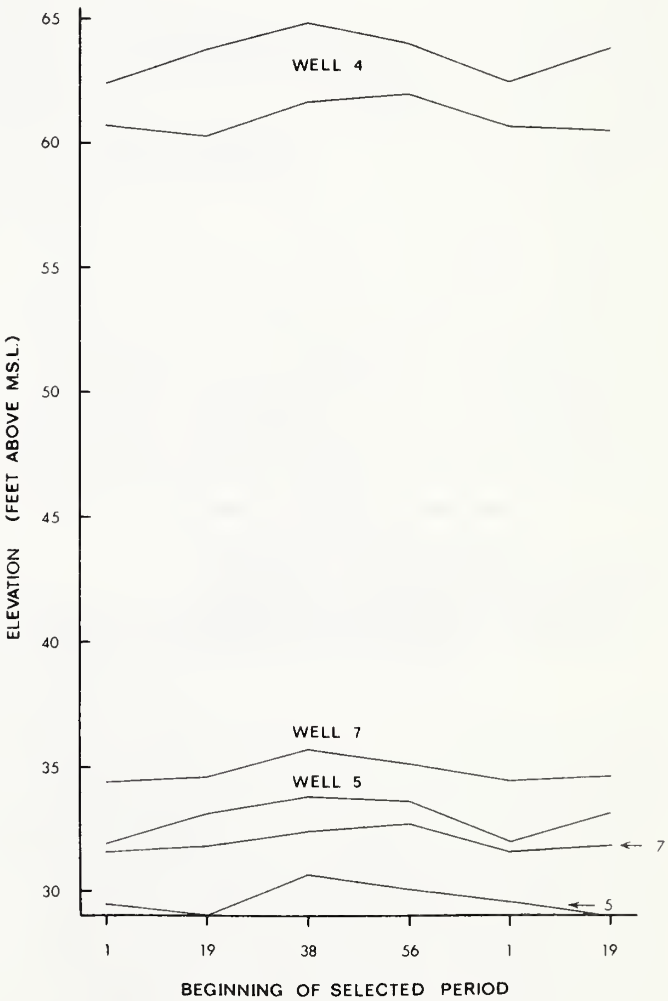

FIGURE 4.43.—Annual cycle of ground-water elevation, 5-day averages for entire record period, wells 4, 5, and 7, 1960–73.

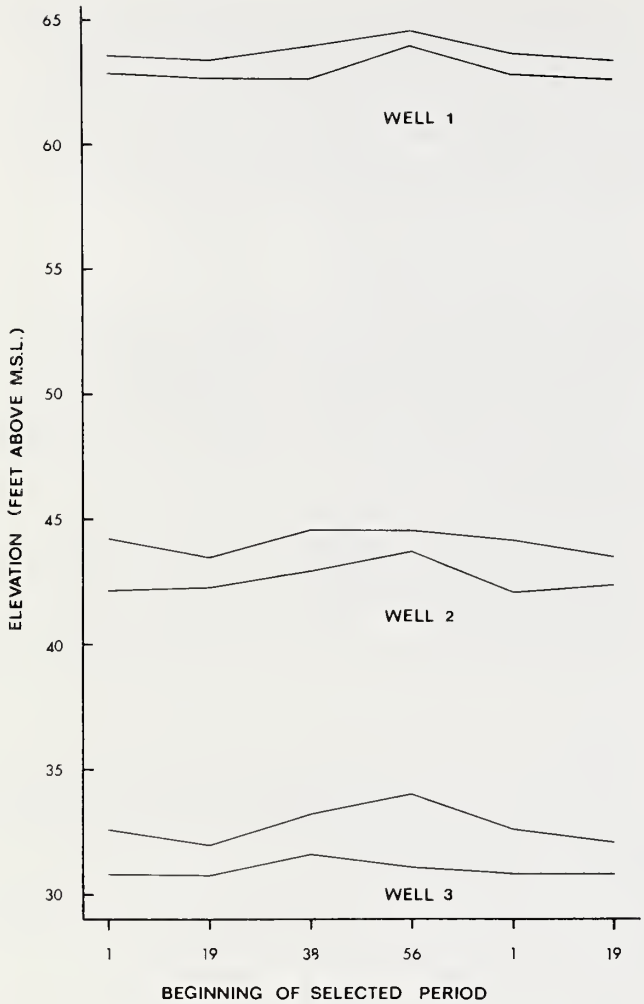

FIGURE 4.44.—Annual cycle of ground-water elevation, 5-day averages for period before channelization, wells 1, 2, and 3, 1960–63.

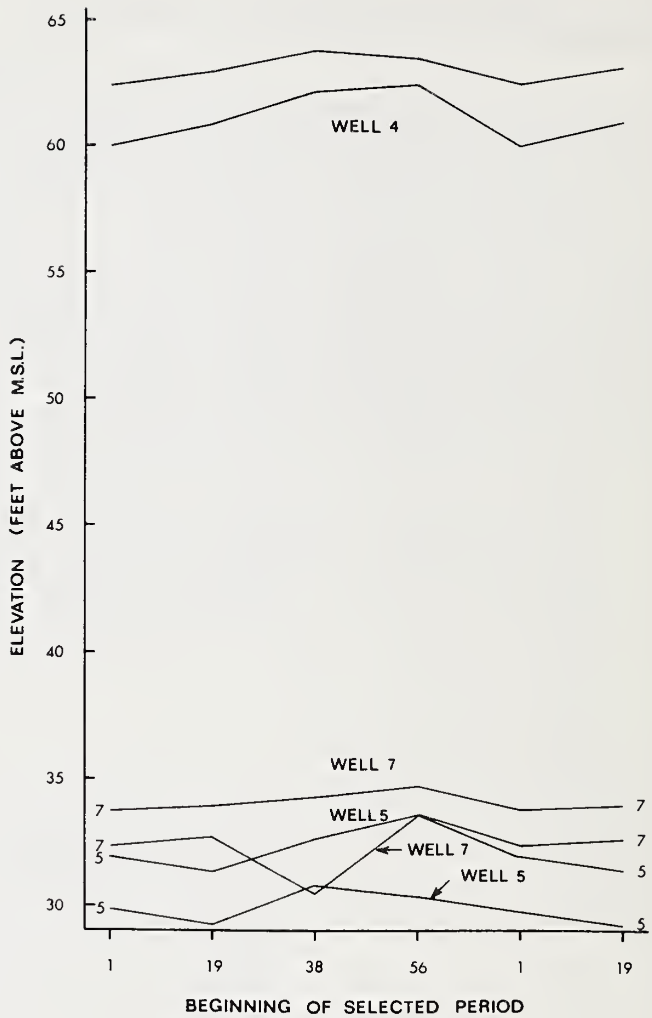

FIGURE 4.45.—Annual cycle of ground-water elevation, 5-day averages for period before channelization, wells 4, 5, and 7, 1960–63.

period. The 5- and 10-day periods show recharge caused by individual rainfall events, while the 30-day averaging periods show the general seasonal patterns. Figures 4.49–4.55 show the medians for wells 1 through 7 for the period 1960–73. The water table in all wells was relatively stable through mid-April (period 20). Recession then occurred until about the first part of June, when recharge started and continued for about 30 days. The water table was then stable until the end of October, when recession started and continued until the end of the year. Pronounced individual recharge periods can be seen on the 5- and 10-day averaging-period graphs. All wells had the same seasonal pattern, and figures 4.49 and 4.52 show the upper-terrace ground-water response. Figures 4.50, 4.51, 4.53, and 4.54 indicate the lower-terrace ground-water pattern.

Figures 4.56–4.62 show the 5-, 10-, and 30-day ground-water averaging periods for the before-treatment period (1960–63). The same patterns are observable for the entire record period. When these figures are compared with figures 4.63–4.67 (1969–72), there is no consequential difference between the ground-water patterns of before- and after-treatment. So comparison of the ranked ordering (maximum and minimum for selected periods and the medians for 5-, 10-, and 30-day averaging periods) shows no

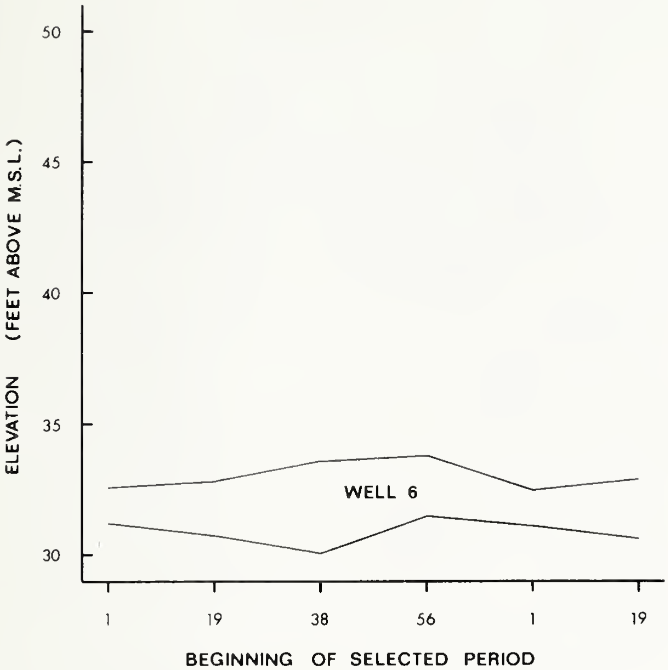

FIGURE 4.46.—Annual cycle of ground-water elevation, 5-day averages for period before channelization, well 6, 1960–63.

significant difference among the ground-water tables for the before-treatment, after-treatment, and entire record periods of any of the observation wells.

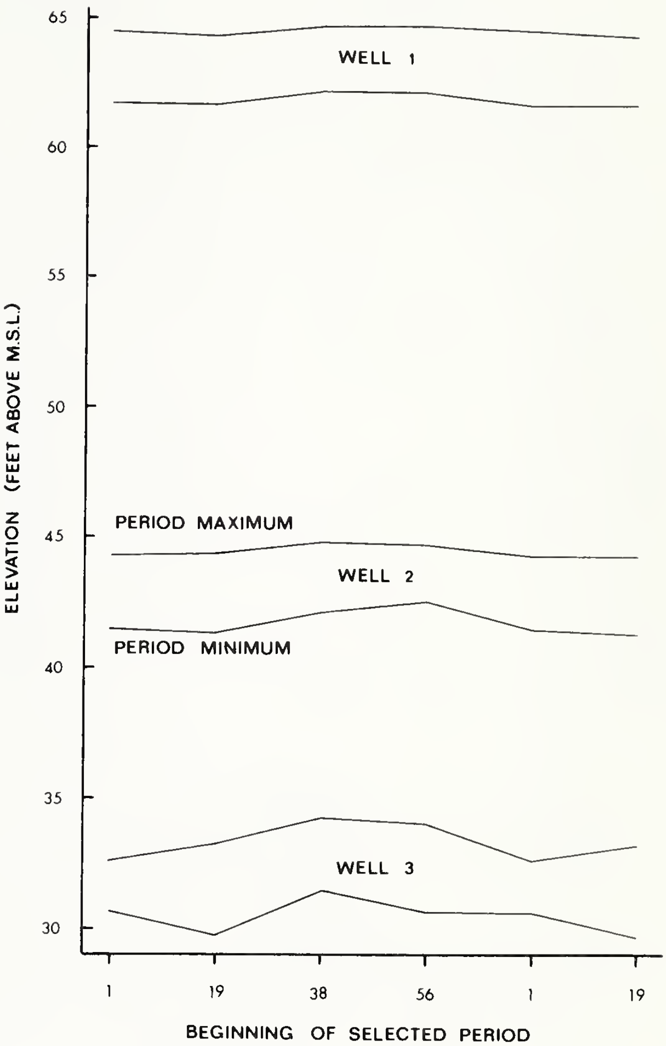

FIGURE 4.47.—Annual cycle of ground-water elevation, 5-day averages for period after channelization, wells 1, 2, and 3, 1969–72.

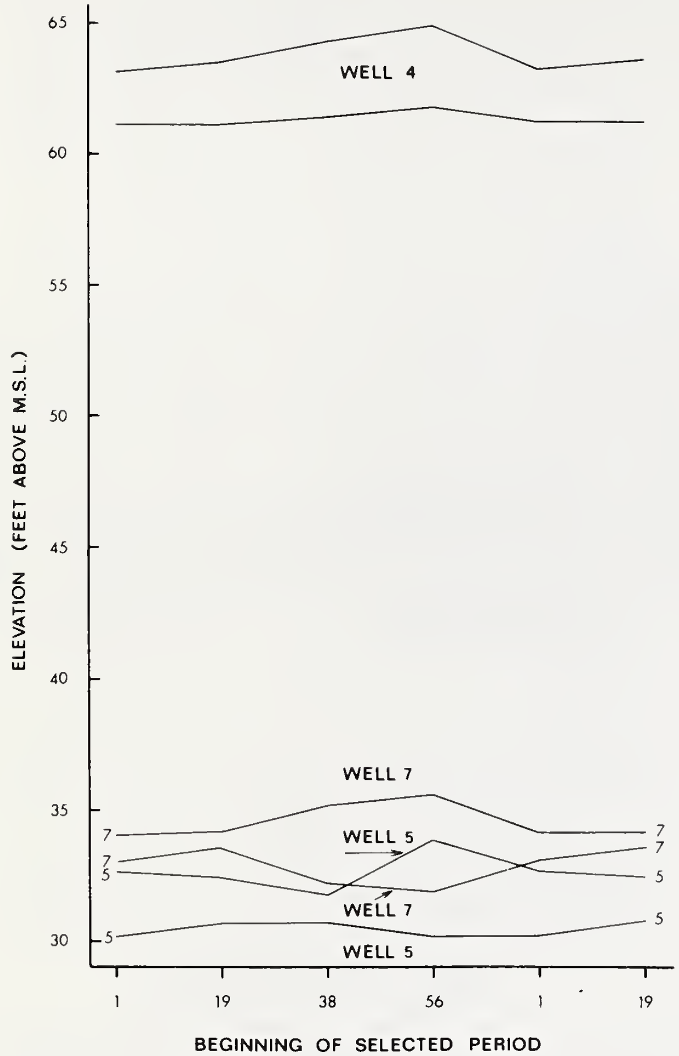

FIGURE 4.48.—Annual cycle of ground-water elevation, 5-day averages for period after channelization, wells 4, 5, and 7, 1969-72.

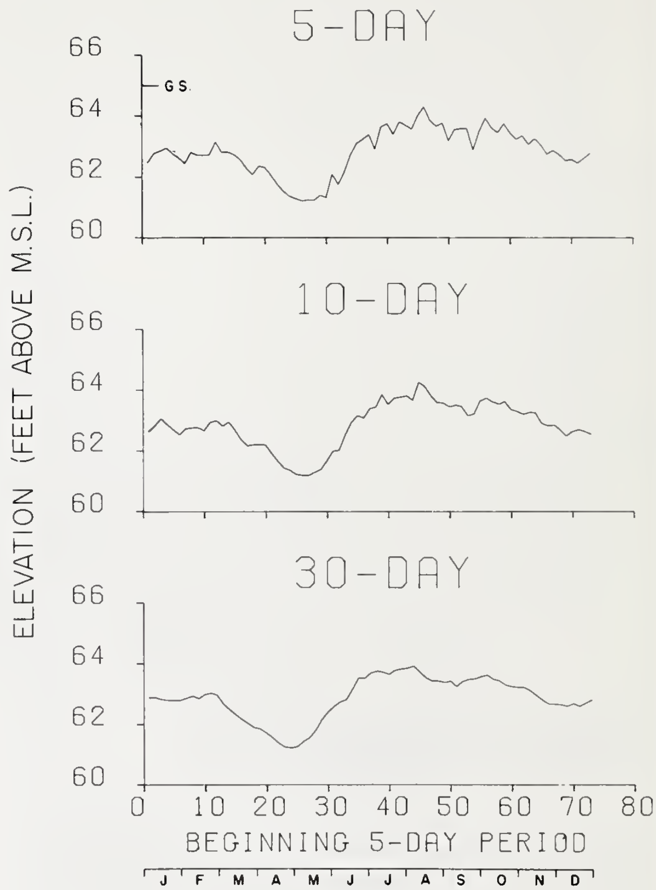

FIGURE 4.49.—Median 5-, 10-, and 30-day ground-water elevations, well 1, 1960-73. (G.S., ground surface.)

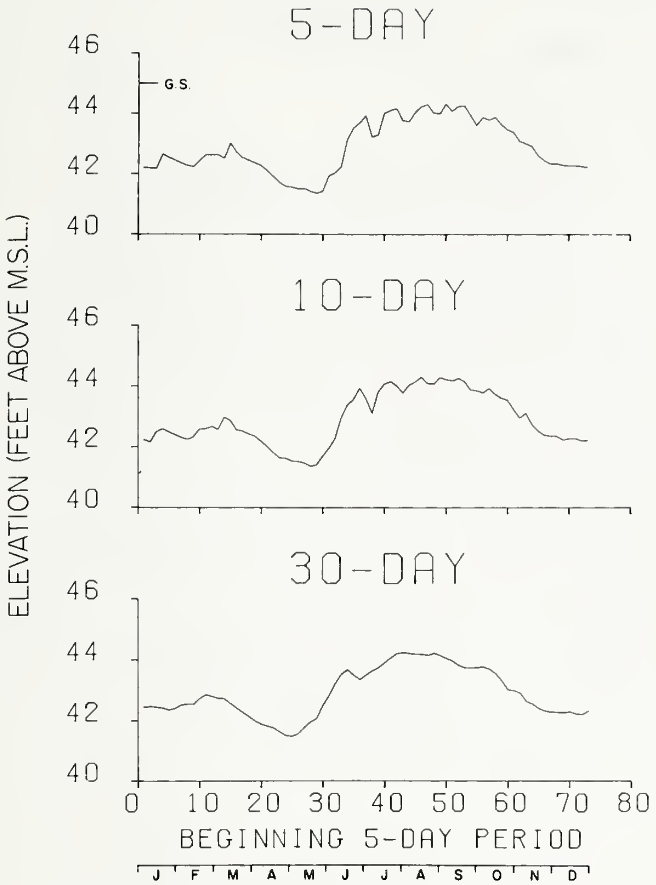

FIGURE 4.50.—Median 5-, 10-, and 30-day ground-water elevations, well 2, 1960–73. (G.S., ground surface.)

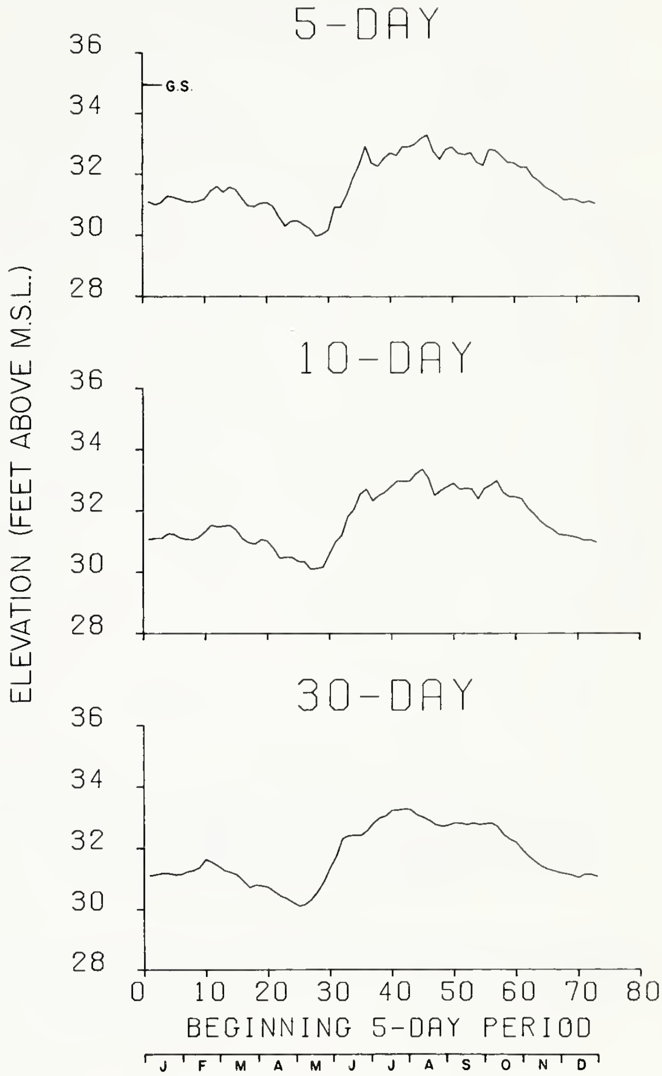

FIGURE 4.51.—Median 5-, 10-, and 30-day ground-water elevations, well 3, 1960–73. (G.S., ground surface.)

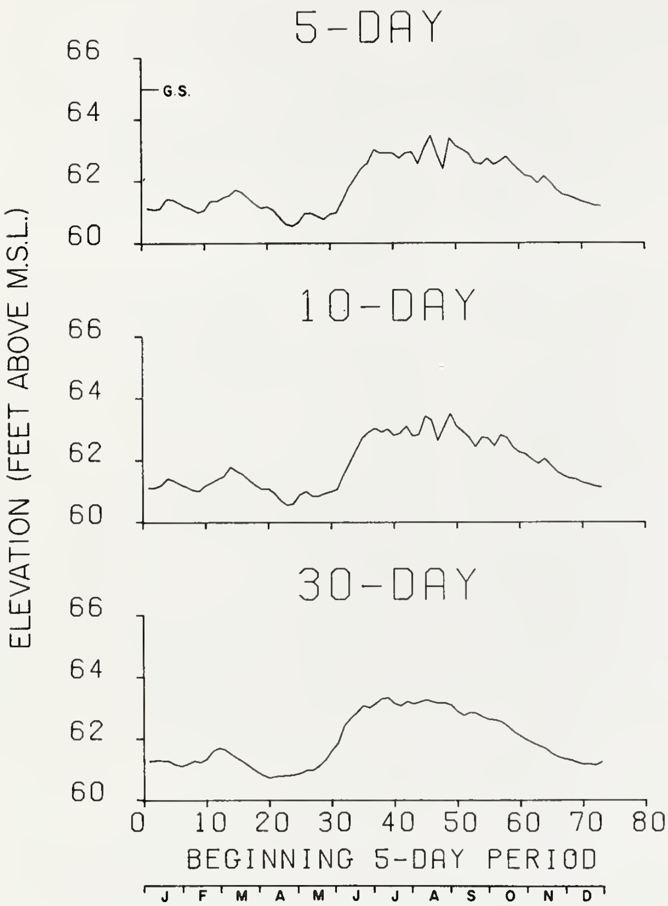

FIGURE 4.52.—Median 5-, 10-, and 30-day ground-water elevations, well 4, 1960–73. (G.S., ground surface.)

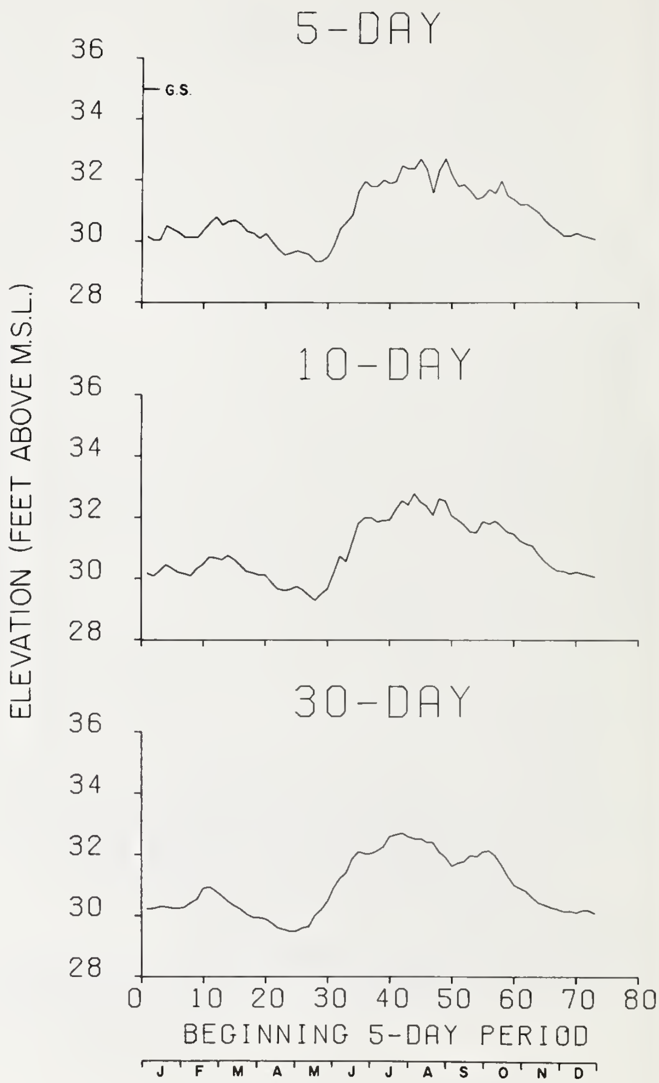

FIGURE 4.53.—Median 5-, 10-, and 30-day ground-water elevations, well 5, 1960–73. (G.S., ground surface.)

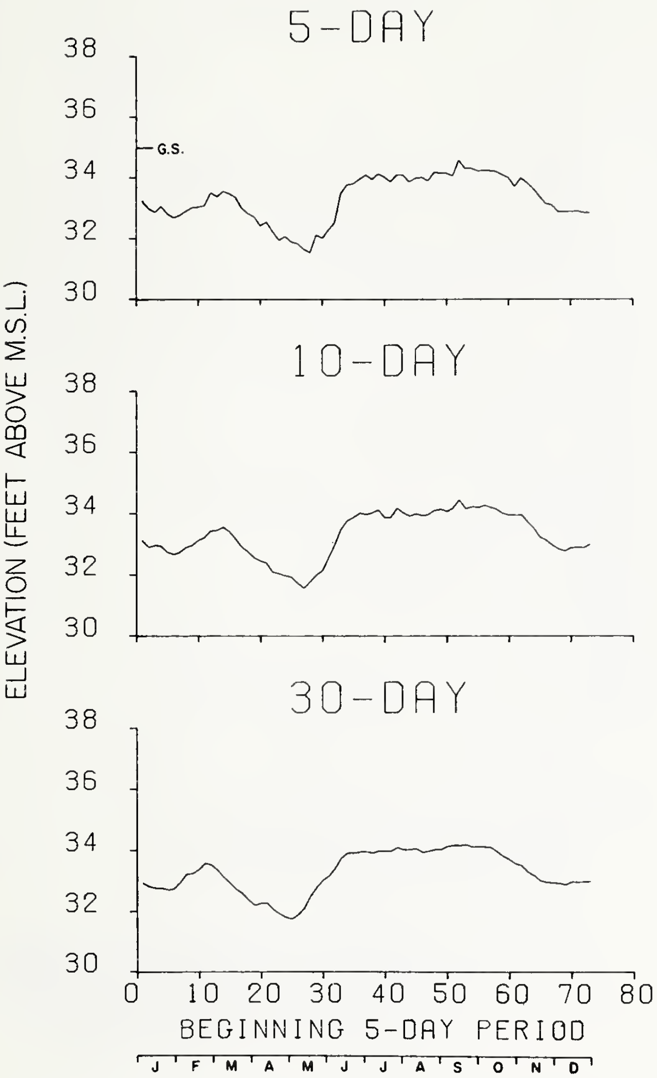

FIGURE 4.54.—Median 5-, 10-, and 30-day ground-water elevations, well 6, 1960–73. (G.S., ground surface.)

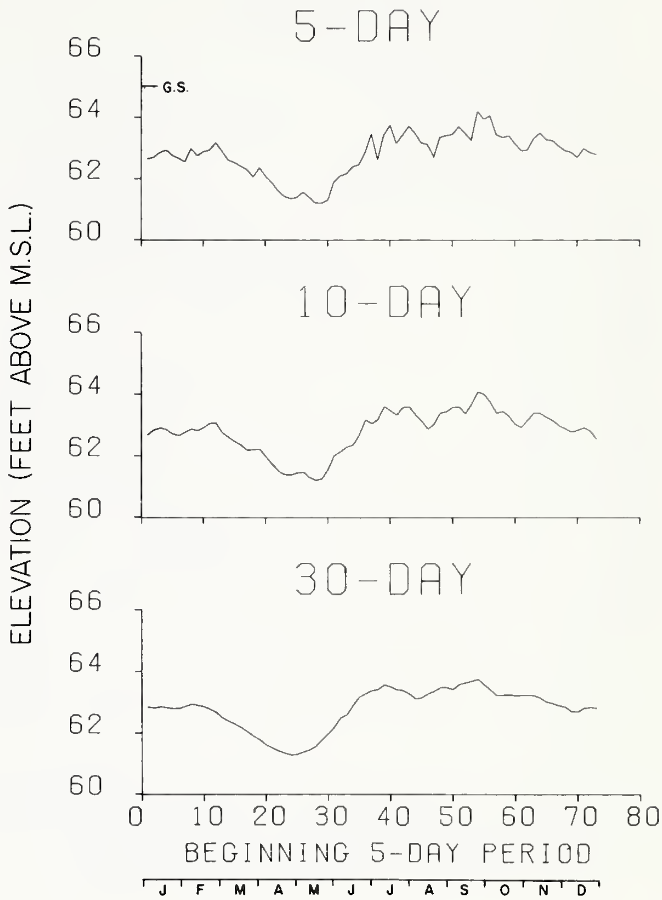

FIGURE 4.55.—Median 5-, 10-, and 30-day ground-water elevations, well 7, 1960–73. (G.S., ground surface.)

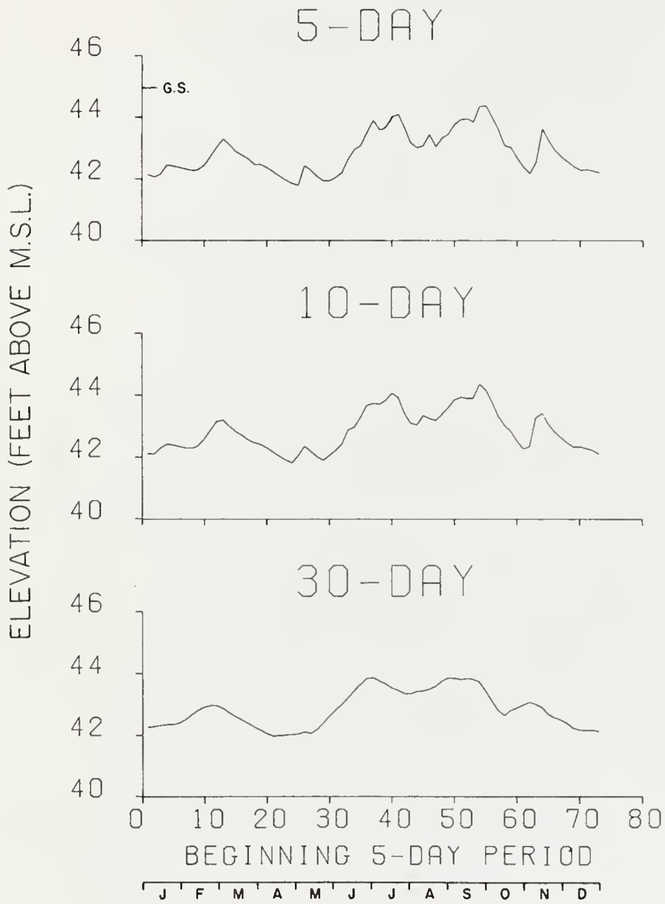

FIGURE 4.56.—Median 5-, 10-, and 30-day ground-water elevations, well 1, 1960–63. (G.S., ground surface.)

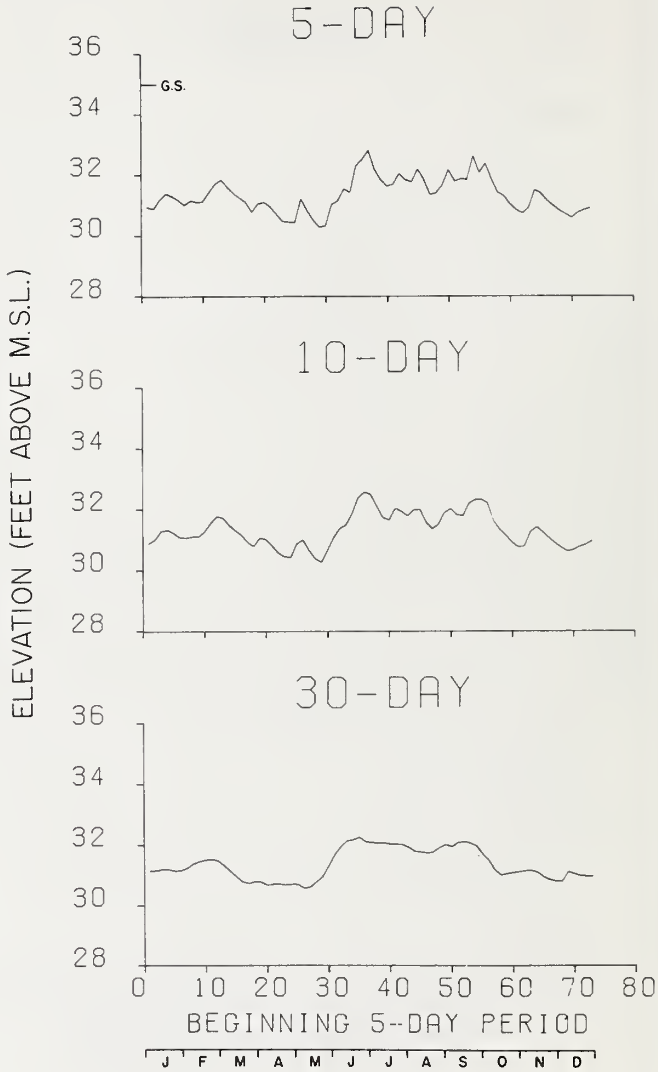

FIGURE 4.57.—Median 5-, 10-, and 30-day ground-water elevations, well 2, 1960–63. (G.S., ground surface.)

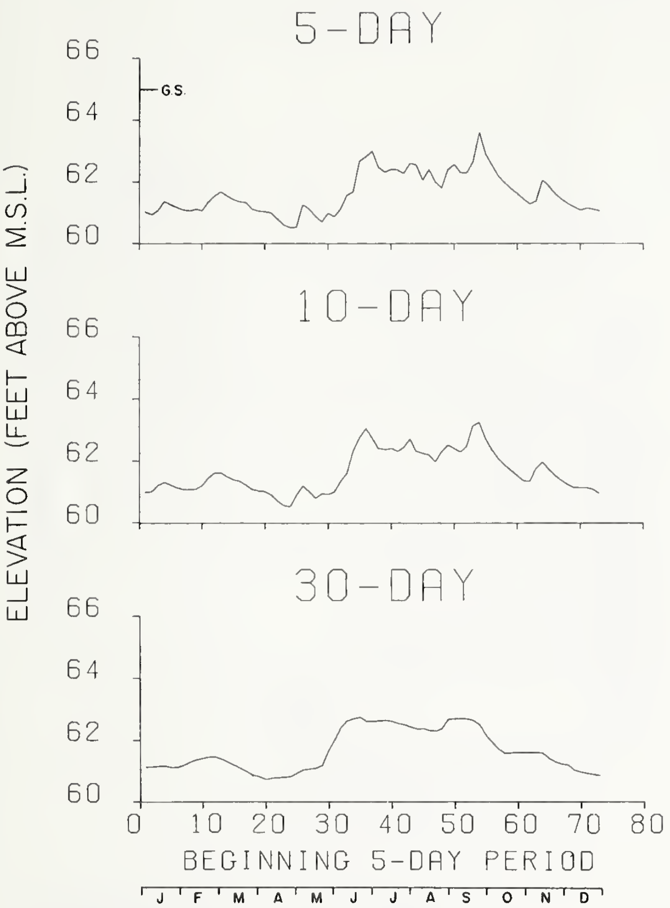

FIGURE 4.58.—Median 5-, 10-, and 30-day ground-water elevations, well 3, 1960–63. (G.S., ground surface.)

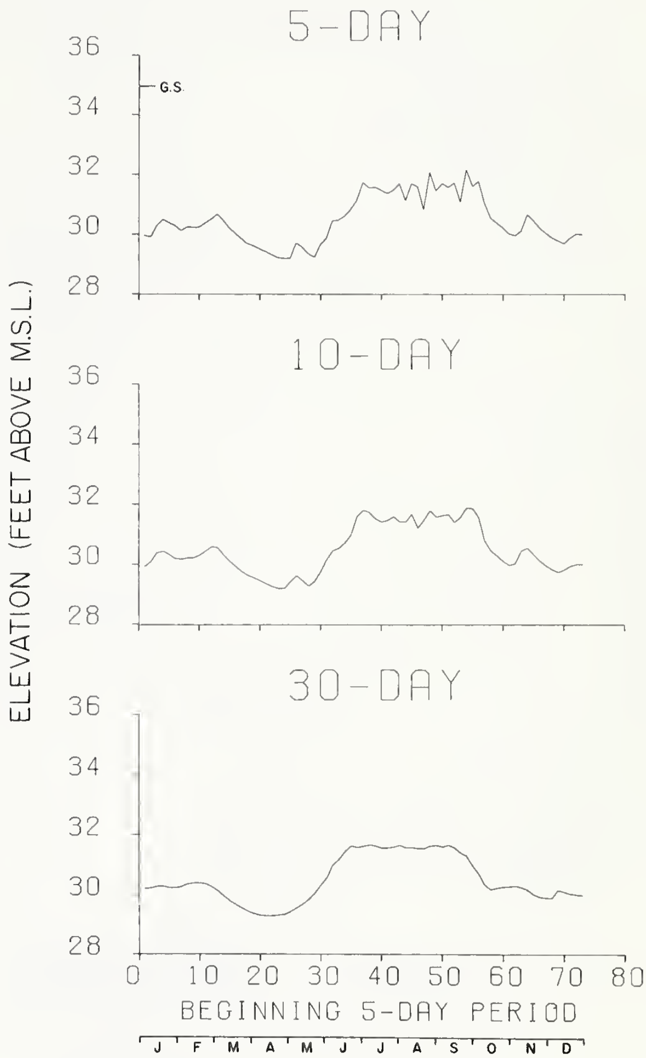

FIGURE 4.59.—Median 5-, 10-, and 30-day ground-water elevations, well 4, 1960–63. (G.S., ground surface.)

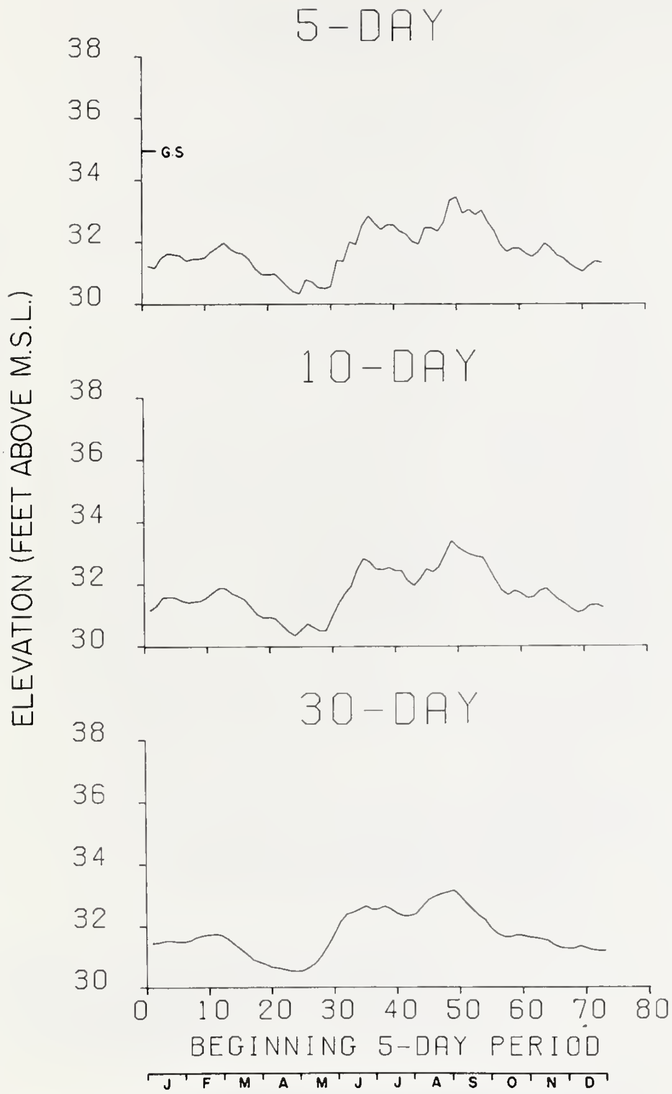

FIGURE 4.60.—Median 5-, 10-, and 30-day ground-water elevations, well 5, 1960–63. (G.S., ground surface.)

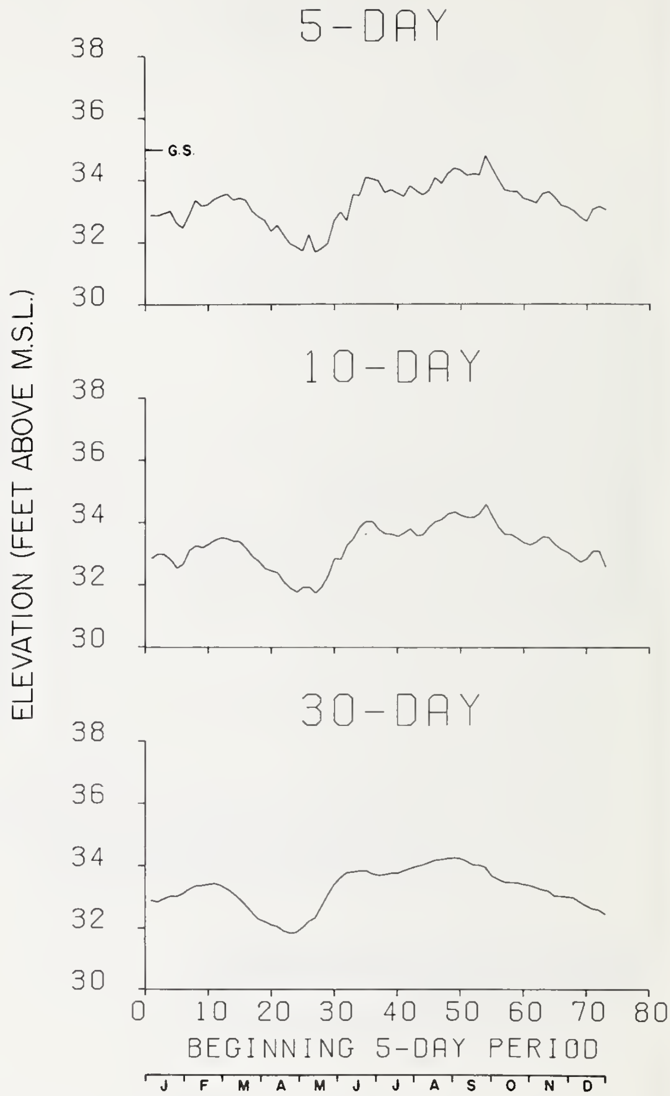

FIGURE 4.61.—Median 5-, 10-, and 30-day ground-water elevations, well 6, 1960–63. (G.S., ground surface.)

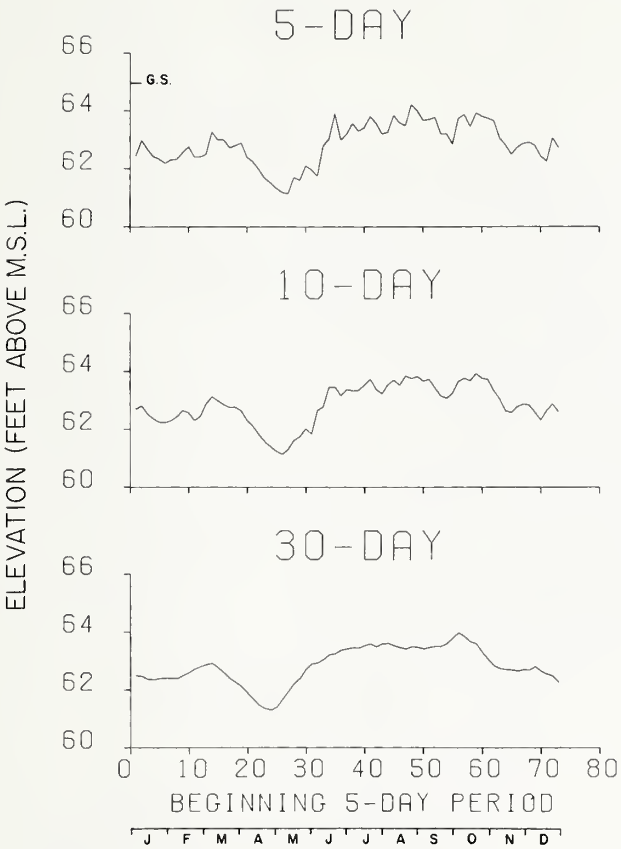

FIGURE 4.62.—Median 5-, 10-, and 30-day ground-water elevations, well 7, 1960–63. (G.S., ground surface.)

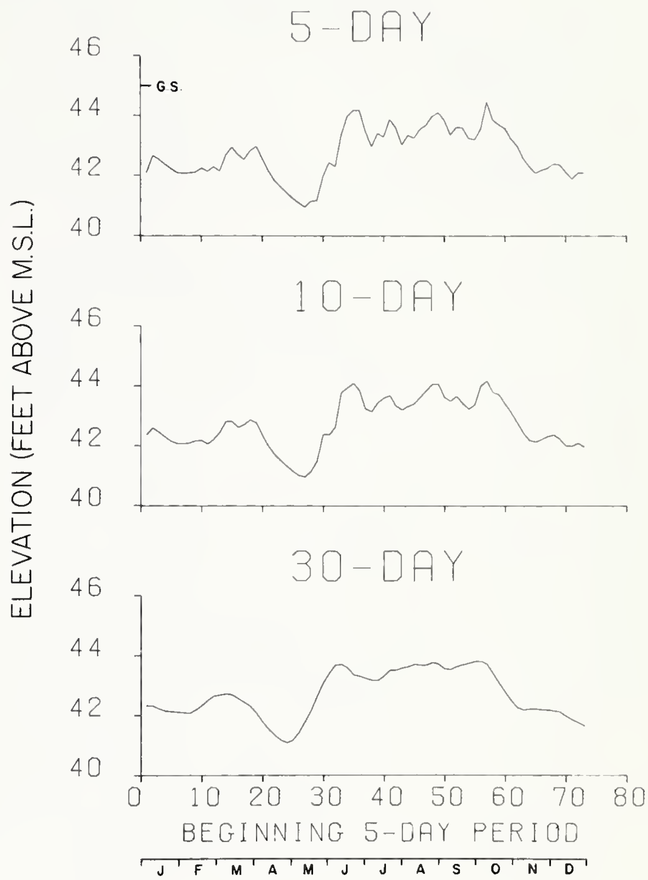

FIGURE 4.63.—Median 5-, 10-, and 30-day ground-water elevations, well 1, 1969–72. (G.S., ground surface.)

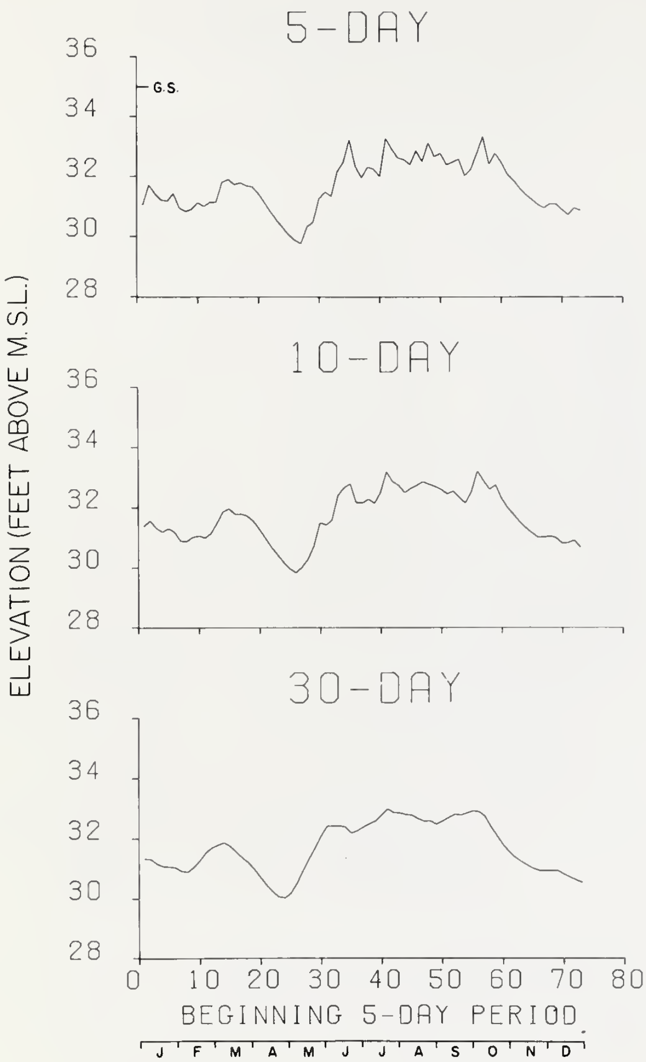

FIGURE 4.64.—Median 5-, 10-, and 30-day ground-water elevations, well 2, 1969–72. (G.S., ground surface.)

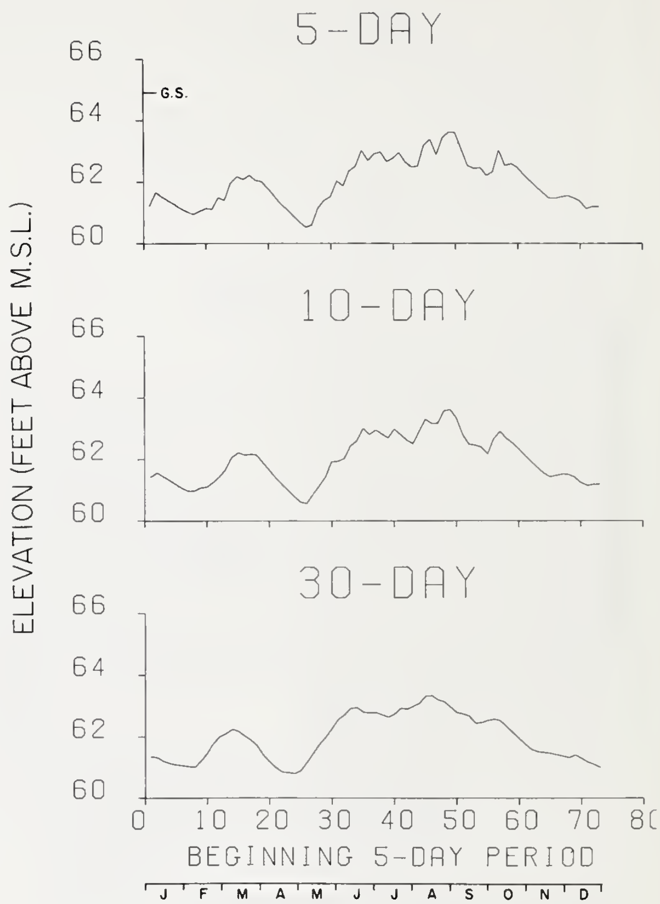

FIGURE 4.65.—Median 5-, 10-, and 30-day ground-water elevations, well 3, 1969–72. (G.S., ground surface.)

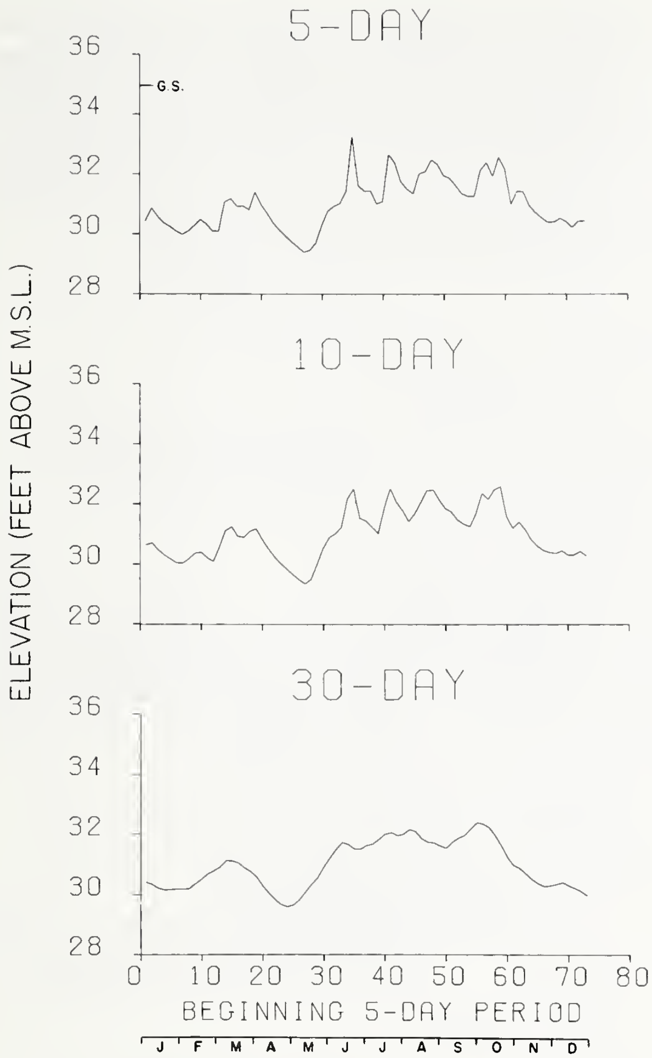

FIGURE 4.66.—Median 5-, 10-, and 30-day ground-water elevations, well 4, 1969–72. (G.S., ground surface.)

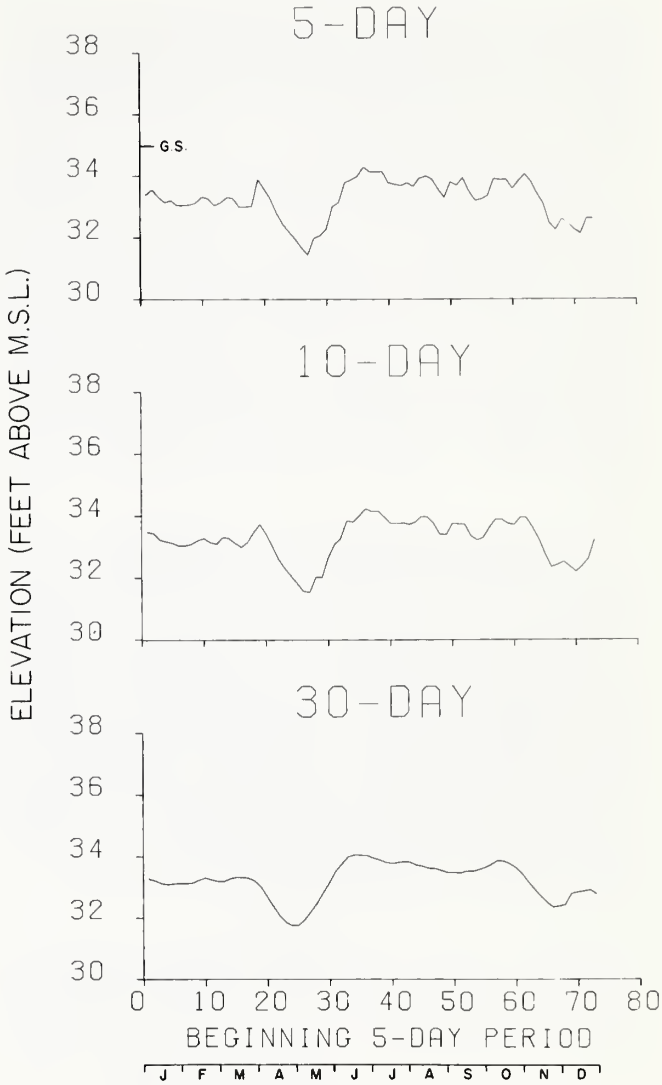

FIGURE 4.67.—Median 5-, 10-, and 30-day ground-water elevations, well 5, 1969–72. (G.S., ground surface.)

The previous section treated the various hydrologic components independently, with only passing reference to climate. This section relates two or more components to determine the interrelationships.

5.1.—Water-Yield Analyses

Water-yield analysis is concerned with the volume of water leaving a drainage area and the distribution of this volume in time. The distribution, in general, considers variability of flow volumes for periods of a month or less, although annual volumes are also treated. Results of yield analysis are useful in planning the utilization of the water resources.

5.1.1.—Annual Precipitation and Streamflow

Monthly and annual precipitation data are given in tables A-5—A-7 for watersheds W-2, W-3, and W-5. Monthly and annual streamflow data are given in tables A-11—A-13. Annual precipitation and streamflow volumes are shown graphically for the three watersheds in figures 5.1-5.3, which also depict variability of precipitation and streamflow from year to year. The same general pattern exists for all watersheds, although there are some apparent differences. Distribution of rainfall within each year may be the significant difference.

The ranges of annual rainfall and streamflow volumes over the period of record possibly indicate some threshold value of precipitation below which streamflow will not occur. These relationships were analyzed for each watershed before and after channel improvement and construction of water-level control structures. Phase I construction in 1962 (table A-10) should have had minimal effect on water yield. This phase did not include any channelization. Main-stream and major-tributary channelization with construction of water-level control structures occurred in the three watersheds in 1964 during Phase II.

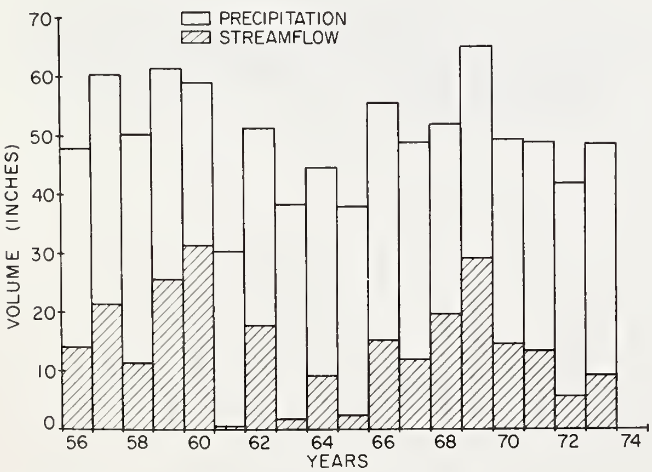

FIGURE 5.1.—Annual precipitation and streamflow, watershed W-2.

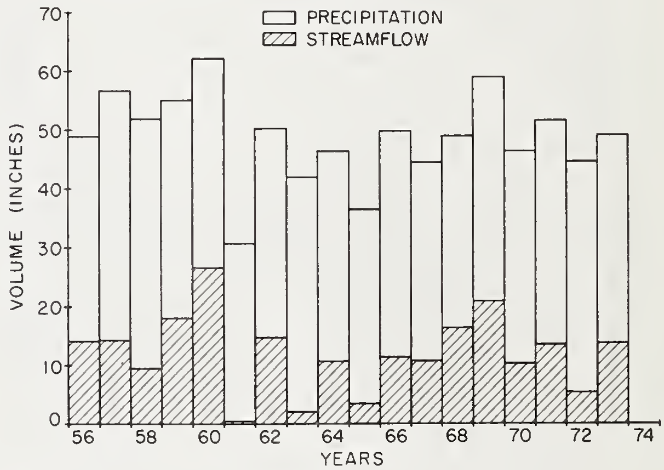

FIGURE 5.2.—Annual precipitation and streamflow, subwatershed W-3.

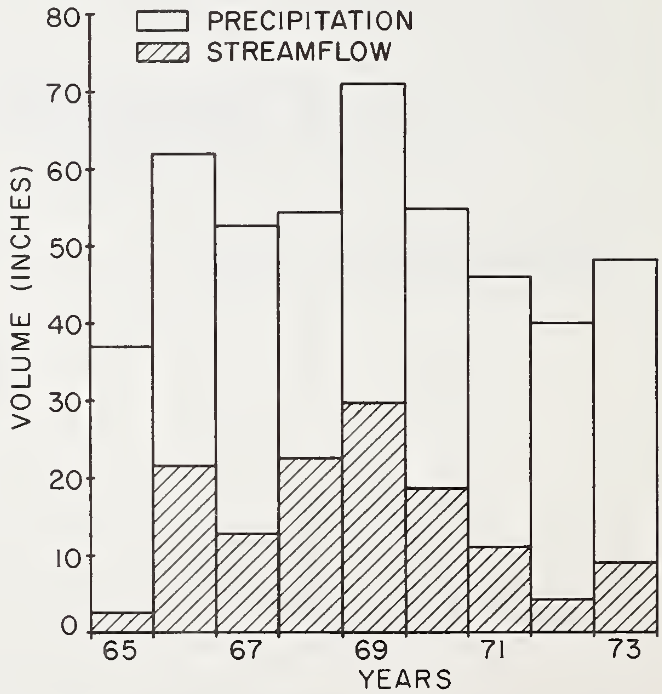

FIGURE 5.3.—Annual precipitation and streamflow, subwatershed W-5.

Annual precipitation-streamflow relationships are shown in figures 5.4–5.6 for watersheds W–2, W–3, and W–5. The before-treatment period of 1956–63 included the lowest annual rainfall and streamflow. The linear relationship for watershed W–2 is

$$Q_a = 0.922P_a - 30.44, \tag{5.1}$$

and for watershed W–3 is

$$Q_a = 0.787P_a - 26.60, \tag{5.2}$$

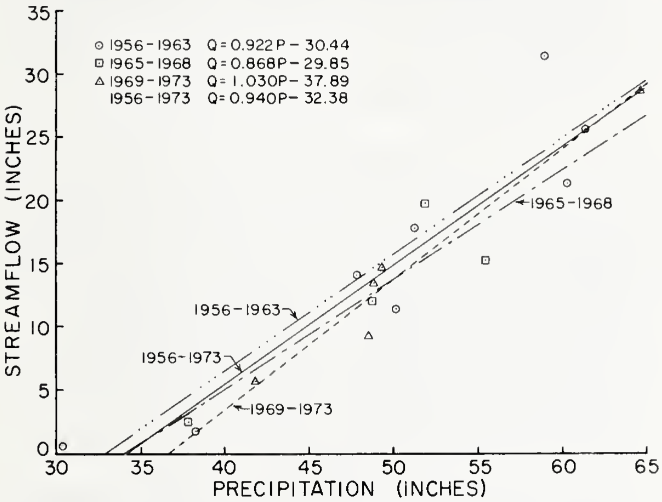

FIGURE 5.4.—Relationship between annual precipitation and streamflow volumes, watershed W–2.

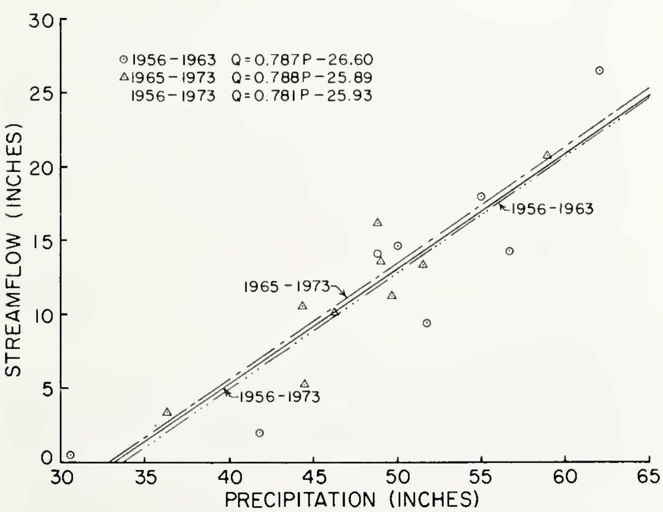

FIGURE 5.5.—Relationship between annual precipitation and streamflow volumes, subwatershed W–3.

where Q_a is annual streamflow in inches and P_a is annual precipitation in inches. There is a statistically significant difference (*64*) between relationships for the two watersheds even though W–3 is a part of W–2 (fig. 1.3). However, the threshold value is essentially the same, 33.02 inches for W–2 and 33.80 inches for W–3, that is the amount of rainfall where streamflow is zero in figures 5.4 and 5.5. In 1961, slightly more than 30 inches of rainfall occurred with approximately 0.5 inch of streamflow at both watersheds.

For the period after channelization at W–3 (1965–73), the regression equation is

$$Q_a = 0.788P_a - 25.89. \tag{5.3}$$

The difference between equations 5.2 and 5.3 is not statistically significant, although the threshold value of 32.86 inches is approximately 1 inch less than the value of 33.80 for the 1956–63 period. These relationships indicate that channelization and water-level control structures result in slightly increased streamflow. The data in figure 5.5 show considerable scatter. A regression equation was determined for all years (1956–73) in order to more easily discern comparative relationships between the short-term and long-term periods; the equation is

$$Q_a = 0.781P_a - 25.93 \tag{5.4}$$

with a threshold value of 33.20.

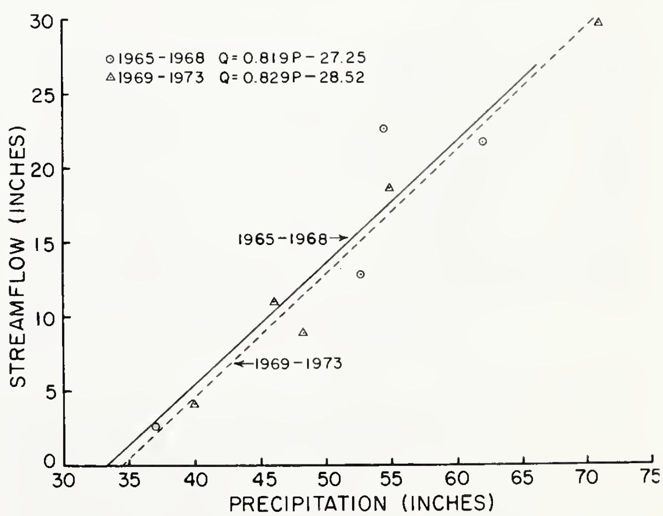

FIGURE 5.6.—Relationship between annual precipitation and streamflow volumes, subwatershed W–5.

Regression equations for W-2 were determined for different periods for comparative purposes. Since Phase III affected W-2, the first after-treatment regression was made for 1969-73 and is given as

$$Q_a = 1.030P_a - 37.89, \tag{5.5}$$

wherein the threshold value changed considerably to 36.78 inches. The 1969-73 period did not include a year with less than 41 inches of rainfall. The difference between equation 5.5 and equation 5.1 is statistically significant. Since the construction of Phase III related only to tributaries of Taylor Creek, period 1965-68 was combined with period 1969-73 for comparative purposes. Also, this total period includes the low-rainfall year of 1965. The regression equation for 1965-73 (not plotted in fig. 5.4) is

$$Q_a = 0.970P_a - 34.80, \tag{5.6}$$

which is significantly different from equation 5.5. The most notable features of the regression lines of figure 5.4 are that both the 1965-73 period (eq. 5.6) and the 1969-73 period (eq. 5.5) indicate that channelization and water-level control structures resulted in a decrease of streamflow compared to the before treatment period of 1956-63. The threshold value for W-2 increased with treatment for either period of comparison. These results would indicate more drainage of the profile or an increase in evapotranspiration. Ground-water duration analysis in section 4.3.2 did not indicate overlowering of the water table after treatment.

Streamflow measurements at W-5 did not begin until 1964; therefore, treatment effects cannot be determined for that area. However, a comparison was made of periods after the Phase II construction to give further validity to the analysis for W-2. Annual precipitation and streamflow volumes for W-5 are shown in figure 5.6, with differentiation between 1965-68 and 1969-73. The regression equation was determined for 1969-73 as

$$Q_a = 0.829P_a - 28.52, \tag{5.7}$$

and for the total period (1965-73) as

$$Q_a = 0.824P_a - 27.95. \tag{5.8}$$

There is no significant difference between the two equations, and the slopes are essentially identical. There is also no significant difference between these equations and the 1965-68 equation (fig. 5.6). Equations 5.7 and 5.8 compare relatively well with equation 5.4 for the entire record period for W-3. The close agreement of equations 5.7 and 5.8 could have been affected by the normal extra input of water by irrigation of citrus in W-5, although the citrus acreage is relatively small part of the total watershed area.

In spite of the variability of annual rainfall and streamflow, watershed treatment did affect water yield. Water yield did not change significantly after treatment at W-3 and decreased after treatment at W-2. These effects may be important in water-supply and water-resource planning.

5.1.2.—4-Month Precipitation and Streamflow

The rainy season in south central Florida normally lasts about 4 months and generally covers the period June through September (fig. 1.12). The season may begin in May or well into June and likewise may end in August or continue well into October. Precipitation-streamflow analysis for multiple-month periods should include the rainy season in a single season. Therefore, a 4-month period was selected for this analysis, with the "average" rainy season, June through September, as one period. This selection resulted in three 4-month periods or "seasons" that did not coincide with a calendar year, but this lack of coincidence was of no real concern. Thus, the following seasons, along with the above season, were used: February through May and October through January.

Since June-September is the rainy season, the October-January season is one of drying out of the normally wet antecedent conditions. Conversely, February-May is the driest season, when antecedent soil water conditions are low. This results in different precipitation-streamflow relationships and further justifies the seasons as selected.

The effects of channelization and water-level control structures on water yield were not known when the study was initiated (sec. 1.1.1, objective 4). Therefore, the precipitation-streamflow analysis was made for each watershed before and after treatment. The effect of transition from a nontreated to a treated condition was not known, so the transition period was treated separately.

Since soils, geology, topography, land use, etc., differ among the watersheds (sec. 1), precipitation-streamflow relationships were determined for each watershed in-

dividually. Data for watershed comparisons are shown later in this section.

Total streamflow resulting from a rainfall event is delayed over a considerable period of time because of soil and ground-water drainage throughout the watershed. The larger a watershed is, the longer the time required for total drainage. There will always be a transient condition, i.e. water in transit in the soil channels, etc. And the shorter the time interval the more pronounced the carryover of transient water conditions. If a storm occurs the last day or during the last several days of a selected interval, most of the associated streamflow may not pass the gaging station until the next interval. Thus, rainfall-streamflow relationships for 4-month intervals may be much more erratic than annual relationships.

Table 5.1.—Periods of rainfall-streamflow analysis by watershed

Watershed	Treatment	Analysis period
W-2	Before-channelization	October 1955–January 1964
	Transition	February 1964–September 1968
	After-channelization	October 1968–January 1974
W-3	Before-channelization	October 1955–January 1964
	After-channelization	October 1964–January 1974
W-5	Transition	June 1964–September 1968
	After-channelization	October 1968–January 1974

Rainfall-streamflow relationships were determined for W-2, W-3, and W-5 for the periods shown in table 5.1. Channelization and construction of water-level control structures were accomplished over different periods in different parts of the total watershed (table A-10). Streamflow measurements for W-5 were started in April 1964 (sec. 2.2). Rainfall-streamflow data for W-2 are shown in figures 5.7-5.9 for the three 4-month seasons. Although there is considerable scatter of the data, attributable to carryover effects, experimental error, etc., particularly for February-May, relatively good linear relationships are exhibited. The transition period has the most scatter and the linear characteristics are not good. Linear regression equations of the general form

$$y=a_o + a_1 \cdot x \qquad (5.9)$$

and correlation coefficients were determined for each season and each period. Regression and correlation coefficients are shown in table 5.2. The correlation coefficients for the transition period at W-2 were low for each season, especially for February-May and October-January. This probably resulted from a relatively poor climatic experience, but channelization and construction

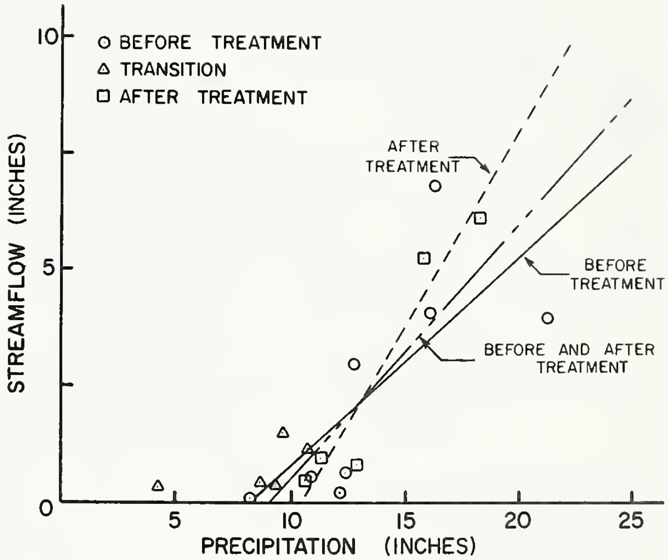

Figure 5.7.—Relationship between precipitation and streamflow volumes, watershed W-2 before, during, and after channelization, February-May.

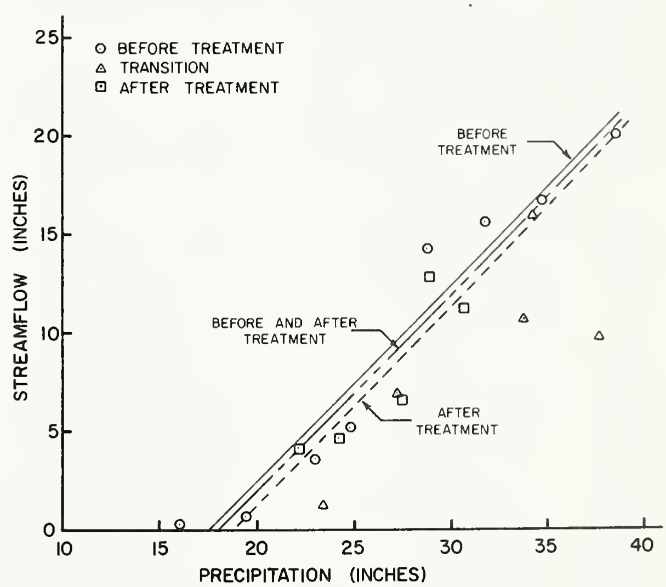

Figure 5.8.—Relationship between precipitation and streamflow volumes, watershed W-2 before, during, and after channelization, June-September.

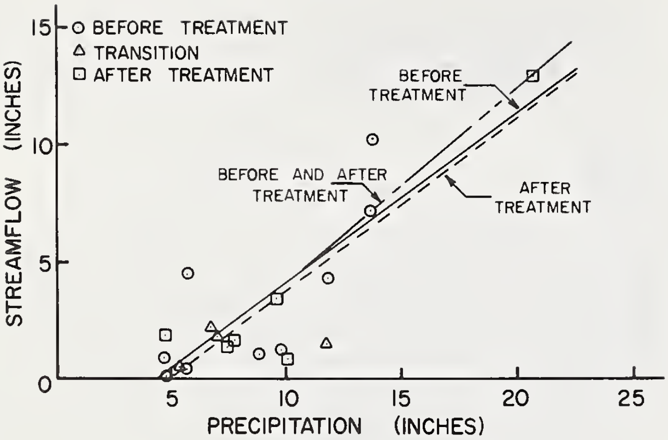

FIGURE 5.9.—Relationship between precipitation and streamflow volumes, watershed W-2 before, during, and after channelization, October-January.

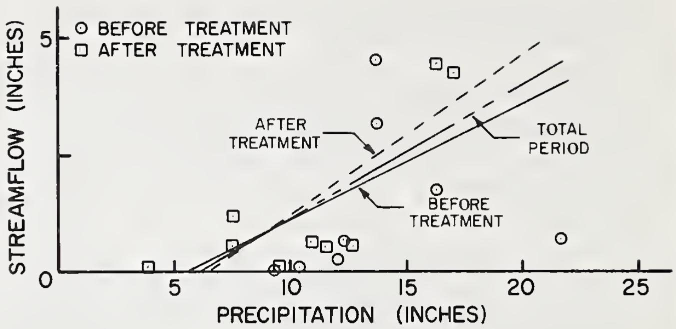

FIGURE 5.10.—Relationship between precipitation and streamflow volumes, subwatershed W-3 before, during, and after channelization, February-May.

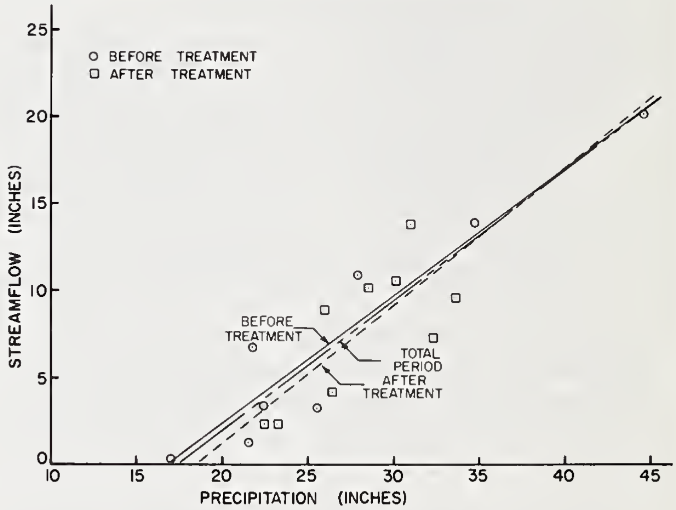

FIGURE 5.11.—Relationship between precipitation and streamflow volumes, subwatershed W-3 before, during, and after channelization, June-September.

could also have affected the relationships. Statistical tests (*19*) of significance were made for the regression coefficients between periods for each season. The differences between coefficients for before treatment and after treatment are not significant at the 95-percent level for June-September and October-January. The differences are significant for the February-May period. The differences in regression coefficients between the transition periods and the before-and after-treatment periods are significant at the 95-percent level. Since differences are not significant for before and after treatment, the difference for the transitional period is primarily attributable to climate. In view of the good comparison for before and after treatment, the periods were combined and relationships were developed; the coefficients are shown in table 5.2. Regression lines are shown in figures 5.7-5.9. The least squares lines in figures 5.7-5.9 show that treatment effects vary considerably by 4-month season. In the February-May period, after-treatment streamflow is greater than before-treatment for higher precipitation amounts. A large precipitation amount in 1957 resulted in low streamflow. This was caused by heavy rainfall late in May after 6 months with rainfall below normal. The combination of dry antecedent conditions and streamflow carrying over into June resulted in low streamflow associated with high rainfall. This one 4-month period biased the before-treatment regression line as shown in figure 5.7. Regression lines for June-September and October-January show little difference due to treatment with only slightly less streamflow after treatment.

Precipitation-streamflow data for watershed W-3 are shown in figures 5.10-5.12 for the three seasons. Regression and correlation coefficients are given in table 5.2. Only 8 months elapsed during channelization and construction of water-level control structures, so a transition period is not shown. Results for W-3 are similar to those for W-2. There is a statistically significant difference at the 95-percent level between regression coefficients for the before- and after-treatment periods for the February-May and October-January seasons (table 5.2). Linear correlation for the two seasons is not as good. The differences in regression coefficients between treatment periods is not statistically significant for the June-

Table 5.2.—Precipitation-streamflow relationships for the 4-month seasons

Season	Treatment period	No. years	Regression coefficient a_0	Regression coefficient a_1	Correlation coefficient	Mean precipitation (inches)	Mean streamflow (inches)
				W-2 watershed			
Feb.-May (fig. 5.7).	Before	8	−3.664	0.443	0.73	13.71	2.41
	Transition	5	−.274	.122	.57	8.43	.76
	After	5	−8.611	.824	.96	13.76	2.72
	Before and after.	13	−4.922	.543	.79	13.73	2.53
June-Sept. (fig. 5.8).	Before	8	−17.317	.989	.97	27.16	9.53
	Transition	5	−14.173	.739	.80	31.26	8.93
	After	5	−18.327	.983	.88	26.63	7.85
	Before and after.	13	−17.860	.992	.96	26.96	8.88
Oct.-Jan. (fig. 5.9).	Before	9	−3.110	.733	.78	8.77	3.31
	Transition	4	1.146	.048	.18	7.73	1.52
	After	6	−3.996	.764	.93	10.08	3.70
	Before and after.	15	−3.347	.740	.86	9.29	3.47
				W-3 watershed			
Feb.-May (fig. 5.10).	Before	8	−1.317	0.244	0.52	13.64	2.01
	After	9	−2.104	.330	.81	10.75	1.44
	Before and after.	17	−1.698	.281	.68	12.11	1.71
June-Sept. (fig. 5.11).	Before	8	−12.486	.741	.95	26.94	7.48
	After	9	−13.637	.751	.74	28.15	7.67
	Before and after.	17	−12.793	.739	.90	27.58	7.58
Oct.-Jan. (fig. 5.12).	Before	9	−3.151	.677	.87	8.75	2.78
	After	10	−2.194	.531	.85	8.64	2.39
	Before and after.	19	−2.645	.600	.86	8.70	2.58
				W-5 watershed			
Feb.-May (fig. 5.13).	Transition	4	7.282	0.206	0.79	8.32	0.97
	After	5	−4.717	.538	.82	13.36	2.47
June-Sept. (fig. 5.14).	Transition	5	−.542	.033	.18	32.91	10.55
	After	5	−16.761	.855	.97	27.74	7.96
Oct.-Jan. (fig. 5.15).	Transition	4	−1.251	.078	.32	8.47	1.91
	After	6	−3.990	.773	.92	10.49	4.12

September season. For June–September (fig. 5.11), the two least squares lines converge at higher precipitation values, with slightly less streamflow after treatment. Regression lines for October–January (fig. 5.12) show that less streamflow occurred after treatment in the higher ranges of precipitation. The relative season relationships for W–3 approximate those for W–2.

For W–5, treatment effects could not be determined. As with W–2, the data for the transition period did not exhibit good linear relations. Regression equations were developed for the transition and after-treatment periods. Figures 5.13–5.15 show the data and after-treatment least squares lines for February–May, June–September, and October–January, respectively. Regression and correlation coefficients are given in table 5.2.

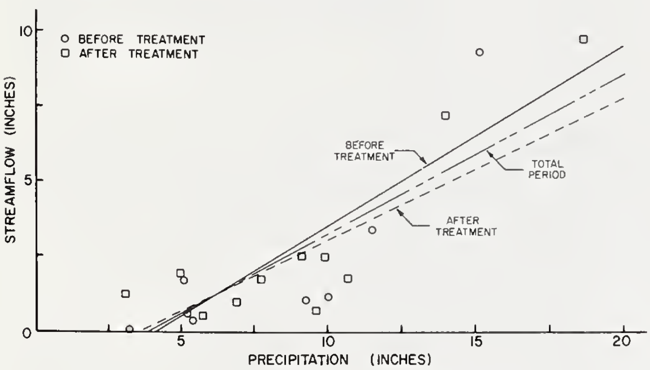

FIGURE 5.12.—Relationship between precipitation and streamflow volumes, subwatershed W–3 before, during, and after channelization, October–January.

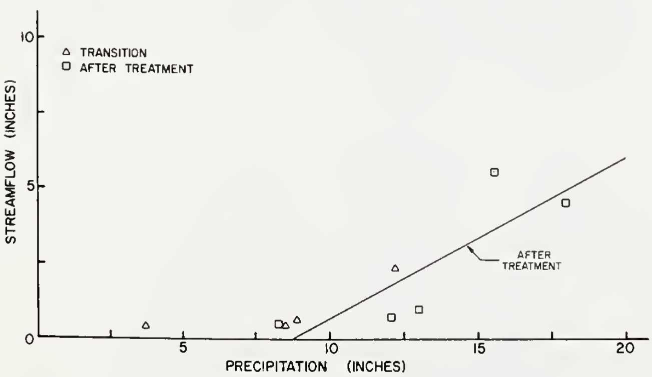

FIGURE 5.13.—Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, February–May.

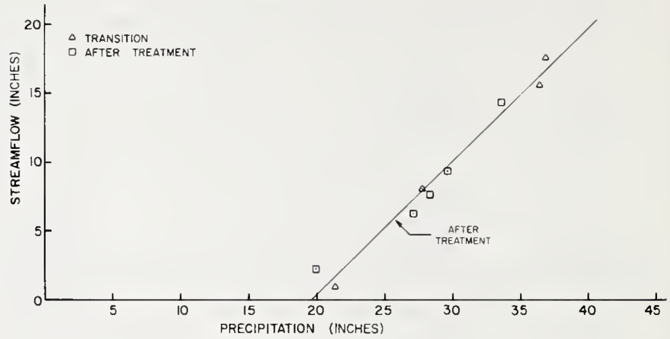

FIGURE 5.14.—Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, June–September.

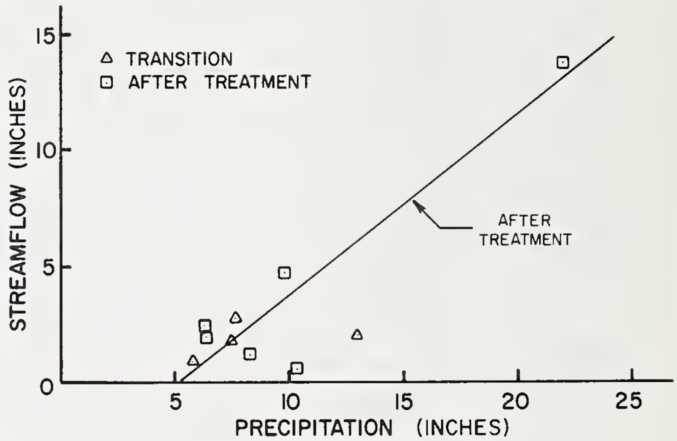

FIGURE 5.15.—Relationship between precipitation and streamflow volumes, subwatershed W–5 before, during, and after channelization, October–January.

Watershed data are shown for comparison in figure 5.16 for all 4-month seasons. Only the average before- and after-treatment least squares line is shown for each watershed each season. Although the relationships were significantly different between periods for February–May, the average for the total period is shown for comparative purposes. The effects of watershed size, land use, soils, etc., are reflected in figure 5.16. For all three 4-month seasons, streamflow was least for W–3, intermediate for W–5, and greatest for W–2. This is also the order of watershed size: 19.1 square miles for W–3, 32.8 for W–5, and 104.5 for W–2. Precipitation-streamflow relationships relative to season are quite distinct in figure 5.16.

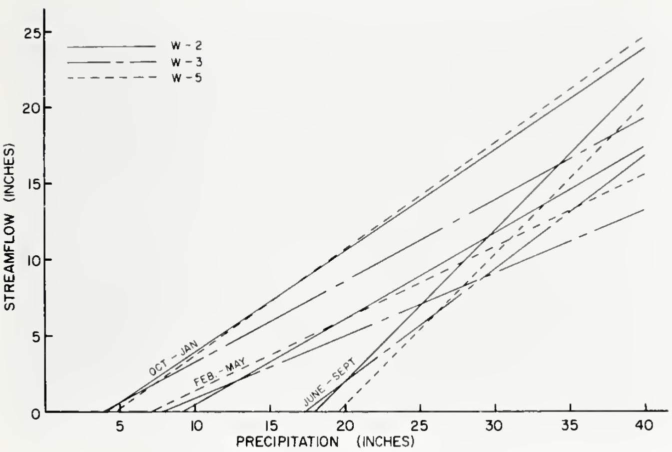

FIGURE 5.16.—Relationship between average precipitation and streamflow volumes by 4-month seasons, watersheds W-2, W-3, and W-5.

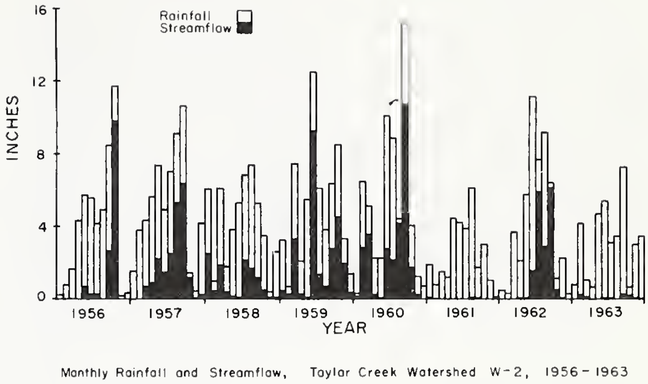

FIGURE 5.17.—Monthly rainfall and streamflow, watershed W-2, 1956-63.

Mean precipitation and streamflow for the combined before- and after-treatment periods for W-2 and W-3 are shown in table 5.2 for each 4-month season. The June-September rainfall is approximately 55 percent of the 12-month total. The June-September streamflow is approximately 65 percent of the 12-month total.

We conclude that watershed treatment did not significantly affect the 4-month water yield. Differences between before- and after-treatment periods are largely attributable to climatic differences. The significantly different relationships during the transition period are largely attributable to climatic experience. That is, the low range of rainfall during the transition years resulted in poorly defined relationships.

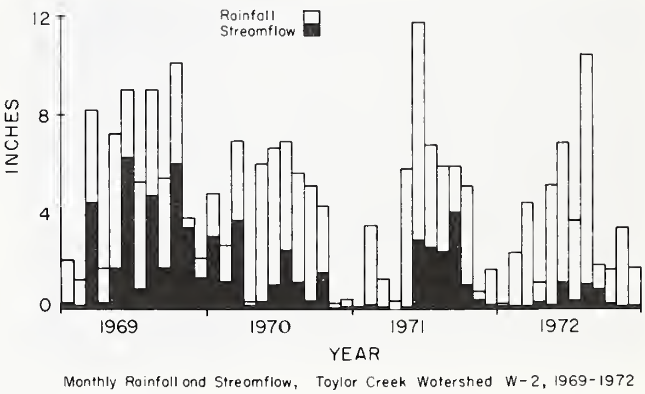

FIGURE 5.18.—Monthly rainfall and streamflow, watershed W-2, 1969-72.

5.1.3.—Monthly Precipitation and Streamflow

The previous section stated that transient-water conditions within a watershed make short-term rainfall-streamflow analyses difficult. The time of occurrence of rainfall relative to the end of a selected time interval further exaggerates the transient conditions. The monthly rainfall and streamflow data reflect the variability (figs. 5.17-5.20).

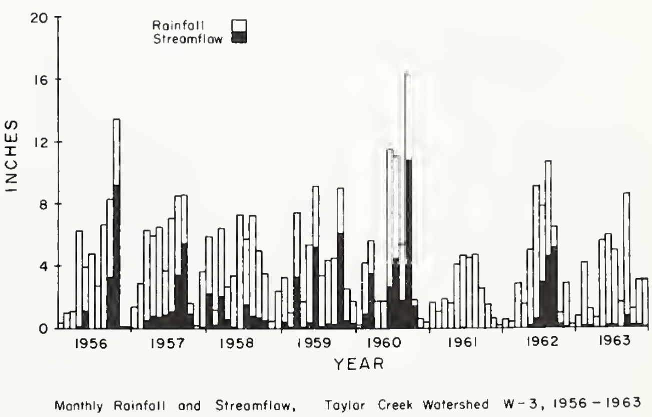

FIGURE 5.19.—Monthly rainfall and streamflow, subwatershed W-3, 1956-63.

Monthly plots of rainfall versus streamflow exhibited considerable scatter that could not be explained by antecedent rainfall or antecedent retention (rainfall minus streamflow) for any finite period. The scatter was of such magnitude that reliable relationships could not be developed and comparisons of relationships for treatment were not meaningful.

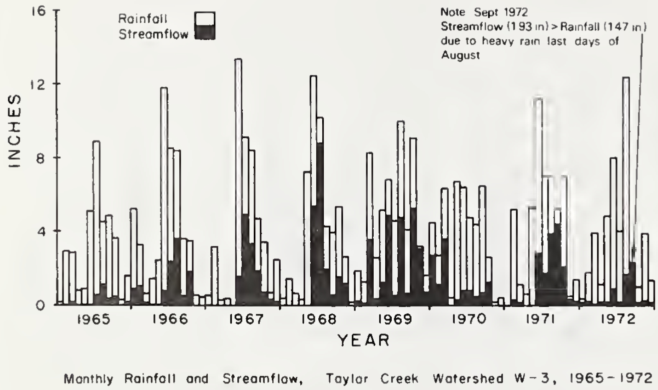

FIGURE 5.20.—Monthly rainfall and streamflow, subwatershed W-3, 1965–72.

FIGURE 5.21.—Improved grass and clover pastures under 2 or more feet of floodwater, Taylor Creek watershed, October 1956. (Photo courtesy of SCS.)

5.2.—Storm Analysis

One of the justifications in section 1 for the selection of Upper Taylor Creek watershed for research was the request received by SCS for drainage and water-level control works under Public Law 566. Also, objective 4 (sec. 1.1.1) was to determine the effects of channel improvements and water-level control structures on storm runoff, water yield, and ground-water levels. The drainage needs were related to getting floodwaters out of the watershed to minimize flooding effects. The need was emphasized by the flood conditions that occurred during a hurricane that produced from 6 to 11 inches of rainfall during the period October 14–16, 1956. This was the largest storm during the record period, beginning in 1955.

FIGURE 5.22.—Inundated U.S. Highway 441 at juncture with Taylor Creek, October 1956. Span of floodwater was 300 yards wide, causing closure of highway to traffic for several hours. (Photo courtesy of SCS.)

FIGURE 5.23.—Residential flooding, Okeechobee, Fla., October 1956. (Photo courtesy of SCS.)

Figures 5.21–5.23 show some of the flooded conditions that occurred during the storm. The photo in figure 5.21, taken in the upper elevations on the Penholoway Terrace, shows improved pastures under 2 or more feet of water. Ground slopes in this area are minimal, and normal drainage is slow. The photo in figure 5.22, taken at the bridge where U.S. Highway 441 crosses Taylor Creek or approximately 3.5 miles north of the city of Okeechobee, shows the inundated highway that was closed to traffic for several hours. Maximum discharge measured by the

USGS a short distance downstream was 6,930 cubic feet per second. The photo in figure 5.23 shows residential flooding in Okeechobee. Although flood plains along Taylor Creek were inundated for about 10 days, flood damage was reported as not being as severe as from floods previously experienced because of the low antecedent water level in Lake Okeechobee.

Although the October 1956 storm was an extreme, smaller floods that occurred relatively frequently resulted in long-term inundations that seriously affected both agriculturists and urbanites. The channel improvements planned at that time and constructed later were to provide quicker drainage of flood waters.

5.2.1.—Streamflow Response to Precipitation

Analysis of streamflow response to precipitation was made with a previously reported model (*40*). The storm hydrograph model was later modified for optimization of parameters using a multiple of events simultaneously (*55*). Details of the model and submodels are not repeated in this publication, but the mathematical formulations of the concepts are given. Major emphasis is placed on results of the analysis.

Model structure.—The model consists of three components, each parametrically defined and numerically evaluated. The three components are (1) retention function, (2) characteristic function, and (3) state function.

The retention function partitions storm rainfall into that portion retained in the soil profile and that portion appearing as streamflow, or effective rainfall, by time increment throughout the storm. The mathematical formulation is

$$r_{t+\Delta t}=r_t-b\left(\frac{P_{\Delta t}+20-r_t}{P_{\Delta t}+20-RL}\right)\left(\frac{P_{\Delta t}-RL}{P_{\Delta t}+RL}\right)(r_t-RL)\Delta t, \tag{5.10}$$

where r_t is the rate of retention in inches per hour at time t, Δt is the incremental unit of time, $r_{t+\Delta t}$ is the retention rate in inches per hour after time lapse Δt, $P_{\Delta t}$ is precipitation in inches per hour during time Δt, and RL is the minimum retention rate in inches per hour. The coefficient b is a mathematical shape parameter of the retention function. The numerical value 20 in equation 5.10 represents the maximum rate of retention. Three terms in the equation are evaluated by optimization techniques: (1) the initial value of the function at time zero or beginning of the storm; (2) the minimum rate of retention, RL; and (3) the shape parameter, b. Any portion of any rainfall increment that is in excess of the retention function is defined as the effective portion for flow generation. Details of the retention function are shown schematically in figure 5.24.

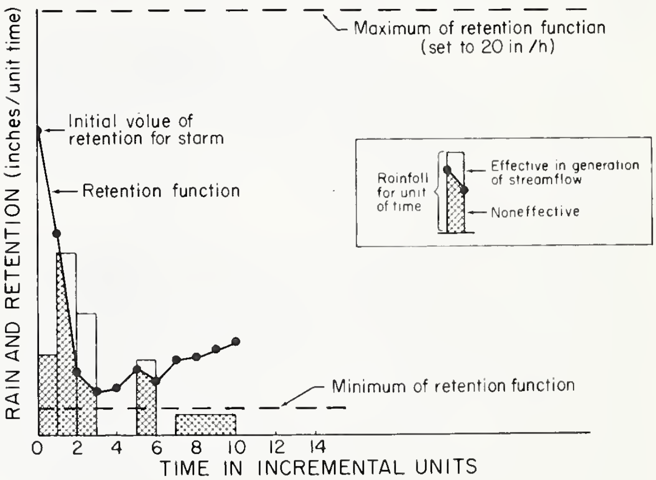

FIGURE 5.24.—Watershed retention function.

The characteristic function is a volume-distribution function, i.e. a histogram of effective rainfall by time increment. The characteristic is a step function defined by five parameters, as shown in figure 5.25. These parameters outline a boundary with a maximum value of $CP1$ at time $CP4$. An angle point with a value of $CP2$ is located at time $CP5$. An additional angle point, $CP3$, is located at a predetermined time twice $CP5$. An end ordinate of the boundary marks the base of the storm hydrograph to be used in analysis. The boundary so outlined marks the height of the steps of the characteristic function at the end of each time increment. Steps intermediate to angle points are calculated by linear interpolation. The end ordinate is computed as that value needed to make the area under the characteristic equal to 1 watershed-inch of volume. A small triangular end-area with height equal to the end-ordinate and with a base equal to the storm base is included. Following construction, the histogram must be rescaled to equal 1 watershed-inch.

Routing of water through the watershed system of channels to the outlet is accomplished with a state function. Channel velocities vary with amount of storage in the

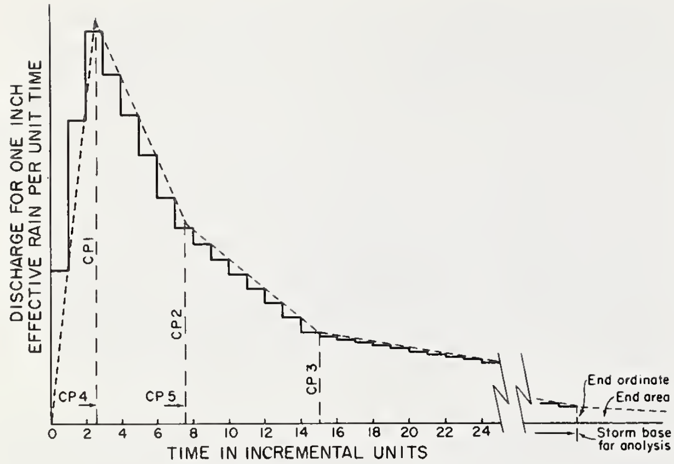

FIGURE 5.25.—Watershed characteristic function.

system, and the state function is a parametric approach to the effect of storage, or state of wetness, on stream response. Analogous to the descending exponential curve as a reasonable approximation of streamflow recession and the drainage of a reservoir with outflow proportional to the volume of water stored, an exponential form was selected as the state function of the hydrograph model. The storage-routing process that varies with volume of storage, based on some storage index, is expressed as

$$I(t)=SP1+SP2(WQ_t/DA+(1-W)P_{\Delta t}/\Delta t. \qquad (5.11)$$

In equation 5.11, $SP1$ and $SP2$ are parameters to be determined empirically by optimization; Q_t/DA is discharge per unit of drainage area at the beginning of a time increment; $P_{\Delta t}/\Delta t$ is the effective precipitation during the increment converted to depth per unit of time; and W is an external weighting term that can be set to any value from zero to 1, where zero represents a storage index based entirely on rainfall or input storage and 1 represents a storage index based entirely on streamflow or output storage. Intermediate values produce a composite storage based on both input and output.

The state function, based on the storage index, is

$$S(\tau)=I(t)\ \exp\ [-I(t)\tau]. \qquad (5.12)$$

Equation 5.12 is the state function continuous in τ, which is relative time within the function. For discrete routing in steps equivalent to the time increment, sequential segments of area under $S(\tau)$ are used as routing coefficients. These segments are computed by integration as

$$a(\tau)=\int_{\tau-1}^{\tau} S(\tau)d\tau. \qquad (5.13)$$

The action of the model in representing watershed processes can now be summarized as follows: the characteristic function is routed to the watershed outlet by the coefficients calculated by equation 5.13. The routed characteristic is the unit response to rainfall in one time increment. The state function varies with storage during each time increment of rainfall duration; therefore, a different unit response is calculated for each increment of rain. Second-stage routing of the sequential volumes of effective rainfall, each by its own unit response function, yields the storm discharge hydrograph.

Parameter optimization.—The storm hydrograph model outlined above is based on a total of 10 mathematical parameters to be determined empirically. Each of these serves a specific purpose in establishing a numerical representation of the watershed process. The retention function contains three parameters, the characteristic function five, and the state function two. The values of the parameters can be expected to vary to some degree from storm to storm. Such variations can be caused by errors in recording instruments, by undetected changes in streamflow rating tables, and by differences between computed and true rainfall in the drainage basin.

A computer program was written to simultaneously determine values of the 10 model parameters from several storms. Practical considerations require that the number of storms for simultaneous optimization be kept relatively small. The program allows use of 7 storms as a maximum, where each storm can have a different hydrograph base of up to 60 time increments and a different duration of up to 25 increments of rainfall. The program searches for best values of all the parameters until the squared differences between the computed and observed discharge ordinates for all storms are minimized simultaneously.

Special treatment was necessary for one parameter, initial retention, which was externally adjusted after a few iterations of the optimization routines. A printer-plot of all storms after five iterations gave rainfall, retention, and predicted and observed discharge hydrographs. Any storm with too much volume of runoff had its initial retention increased. Any storm with too little runoff had its initial retention decreased. Another series of iterations of optimization was performed, and the process was continued until correlation coefficients reached approximately 0.95. We emphasize that only relative initial retentions were ad-

justed externally. These values were still parametrically optimized. All nine remaining parameters, including the remaining two in the retention function, were optimized internally with no external controls.

Selection of events for parameter optimization.—Section 2.2 pointed out that the lack of records of Tainter-gate operations at structure S–1 resulted in reduced accuracy of storm streamflow data after channelization. This markedly affected the quality of records for watershed W–2 during the after-treatment period. Therefore, it was decided that hydrograph analysis using the above model would not be attempted for W–2. Only data from W–3 were used in the analysis; the results are given in this section.

Storm selection for hydrograph analysis was made with the following criteria:

(1) Rainfall volumes were similar at the two rain gages.

(2) Significant streamflow volumes resulted from each storm.

(3) Storm hydrographs were single-peak events.

(4) A range of antecedent conditions (degree of watershed wetness) was represented.

(5) Events were selected from the period before channelization and from the period after channelization.

(6) The after-channelization storms selected were those during which the single Tainter gate was completely closed or completely open throughout the storm duration; i.e. gate opening was not changed during the storm.

We anticipated that a list of storms could be obtained for the winter season and a list for the summer season. However, winter and spring encompass the dry period, and storms that occurred during the dry period were either too long or produced multiple-peak hydrographs. The selection resulted in four suitable storms before channelization and four storms after channelization. Also, we anticipated that a number of large-volume storms and small-volume storms could be obtained, but this effort, too, proved unsuccessful. Since most storms occurred during the rainy season, a rather small range of antecedent wetness was obtained. The largest storm on record, the tropical storm of October 14, 1956, was included in the list. No event after channelization was comparable in magnitude to the 1956 storm. The optimized parameters may be slightly biased because of the relative order of magnitude of the 1956 storm. Table 5.3 lists the storms and gives the associated rainfall and streamflow volumes. The spectrum of storms in each list is not what was originally envisioned nor does it represent the desired conditions. A time increment of 2 hours was used, since it was anticipated that the watershed response was somewhat sluggish.

Table 5.3.—Selected storms and associated rainfall and streamflow volumes for hydrograph analysis, subwatershed W–3

Storm date	Weighted rainfall (inches)	Storm streamflow (inches)
	BEFORE CHANNELIZATION	
Sept. 18, 1956	2.36	0.26
Oct. 14, 1956	11.02	9.33
Jan. 25, 1959	2.53	.34
June 17, 1959	5.62	4.25
	AFTER CHANNELIZATION	
Sept. 13, 1967	1.12	0.68
Oct. 2, 1969	3.82	2.27
Jan. 6, 1970	1.45	.27
June 25, 1971	1.33	.51

Results of optimization, before treatment.—The 10 parameters of the model were optimized over the 4 storms simultaneously. A correlation coefficient of 0.992 was determined between the observed and computed scaled hydrographs. Incremental storm rainfall, retention, and observed and computed hydrographs are shown in figure 5.26 for the before-treatment period. As indicated by the high correlation coefficient, the observed and computed hydrographs are in good agreement. The computed hydrograph peaks after the observed hydrograph in each of the first three storms but peaks before the observed hydrograph in the last storm. The magnitude of the storm of October 14, 1956, relative to the other storms, could indicate that parameter optimization may be biased toward that hydrograph shape. Optimized parameter values are given in the first line of table 5.4 for the before-treatment period. The parameter for initial value of the retention function is not shown, since values for individual storms were externally adjusted. The high degree of correlation between observed and computed hydrographs indicates good approximation by the model concepts of the streamflow response to precipitation. The parameter values shown in table 5.4 are hydrologically rational.

Table 5.4.—Optimized values of parameters and correlation coefficients for streamflow-response model before and after channelization, subwatershed W-3

Period	Retention parameters: Shape parameter	Retention parameters: Minimum retention	Characteristic function[1]: $CP1$	$CP2$	$CP3$	$CP4$	$CP5$	State function parameters: $SP1$	$SP2$	Storage (W)	Correlation coefficient
Before treatment	0.1498	0.0020	763	321	111	1.87	5.46	0.0963	0.152	0.65	0.992
After treatment	.0546	.0120	861	185	118	2.81	8.24	.0295	1.428	.65	.992

[1]See figure 5.28.

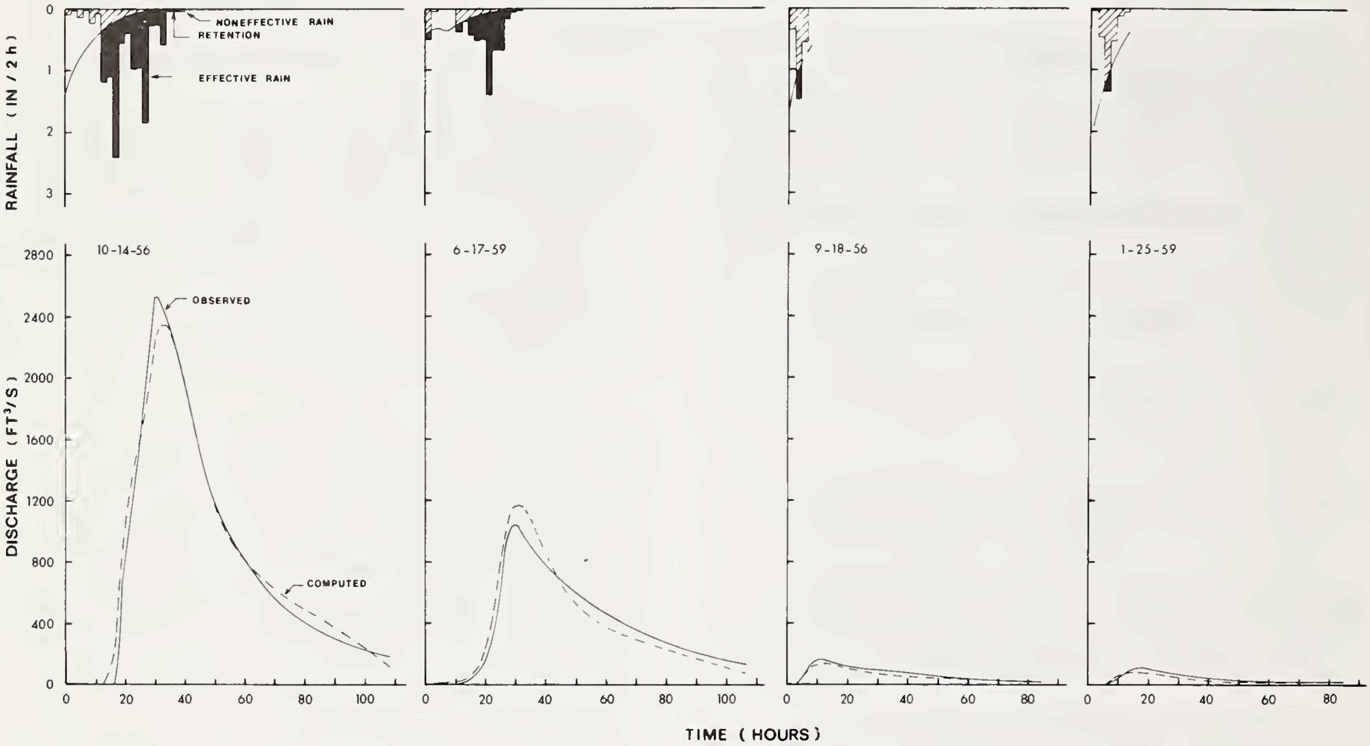

FIGURE 5.26.—Computed and observed hydrographs, subwatershed W-3 before channelization.

Results of optimization, after treatment.—Model parameters were optimized over the four after-treatment storms. No constraints were placed on any parameter based on knowledge gained from the analysis of before-treatment storms. For the after-treatment period, we proceeded as though we had no knowledge of the before-treatment results. Optimized parameter values for the after-treatment storms are also shown in table 5.4. As stated above, the parameter values are hydrologically rational, and again the correlation coefficient between observed and computed hydrographs is 0.992. Computed and observed hydrographs are shown in figure 5.27.

Comparison of optimized parameters before and after treatment.—Since one of the objectives of the research project was to determine the effects of channelization and

water-level control structures on storm runoff, model parameters were compared for the two periods (table 5.4). Storm characteristics affect optimized parameter values. Also, errors of measurement such as recorder error, differences between actual watershed rainfall and computed rainfall using two rain gages, human error in reading charts, etc. can effect the optimized parameter values. These stochastic errors may be in the same direction or may be in opposite directions, and the resultant effects can be significant. With this limitation and the fact that the after-treatment period did not include any storm equivalent in magnitude to the storm of October 14, 1956, and that the drainage areas changed after treatment, the parameter values in table 5.4 are generally in good agreement.

Differences in optimized model parameters for before- and after-treatment periods are hydrologically rational. The shape parameter of the retention function for the after-treatment period is approximately 25 percent of that before treatment. This indicates that the infiltration (retention) curve is considerably flatter and changes very little from one time increment to the next. However, the minimum retention parameter is one order of magnitude greater after treatment than before treatment. The result is a slightly higher total retention. Higher total retention produces slightly less runoff volume for the period of storm runoff. This net difference is small, and part of the retention (infiltrated) rainfall is available for delayed drainage from phreatic ground water.

It should be recalled from discussion of the model concepts that the characteristic function is not a unit hydrograph, but rather a volume-distribution function of potential runoff. With this limitation, the shape of the two characteristic functions before and after treatment (fig. 5.28) rationally represent treatment effects. The delayed peak of the after-treatment characteristic function (*CP*4, table 5.4) indicates that potential runoff is sustained later in the total time base. Characteristic-function parameter *CP*5 (time to angle point) is essentially the same before and after treatment. The characteristic function peak, *CP*1, is greater after treatment, which is consistent with the increase in area drained for the after-treatment period. State function parameter *SP*2 after treatment is an order of magnitude greater than *SP*2 before treatment. The greater value after treatment indicates a greater effect of streamflow on channel storage in routing, which would be expected for larger channel cross sections (greater storage) with water-level control structures.

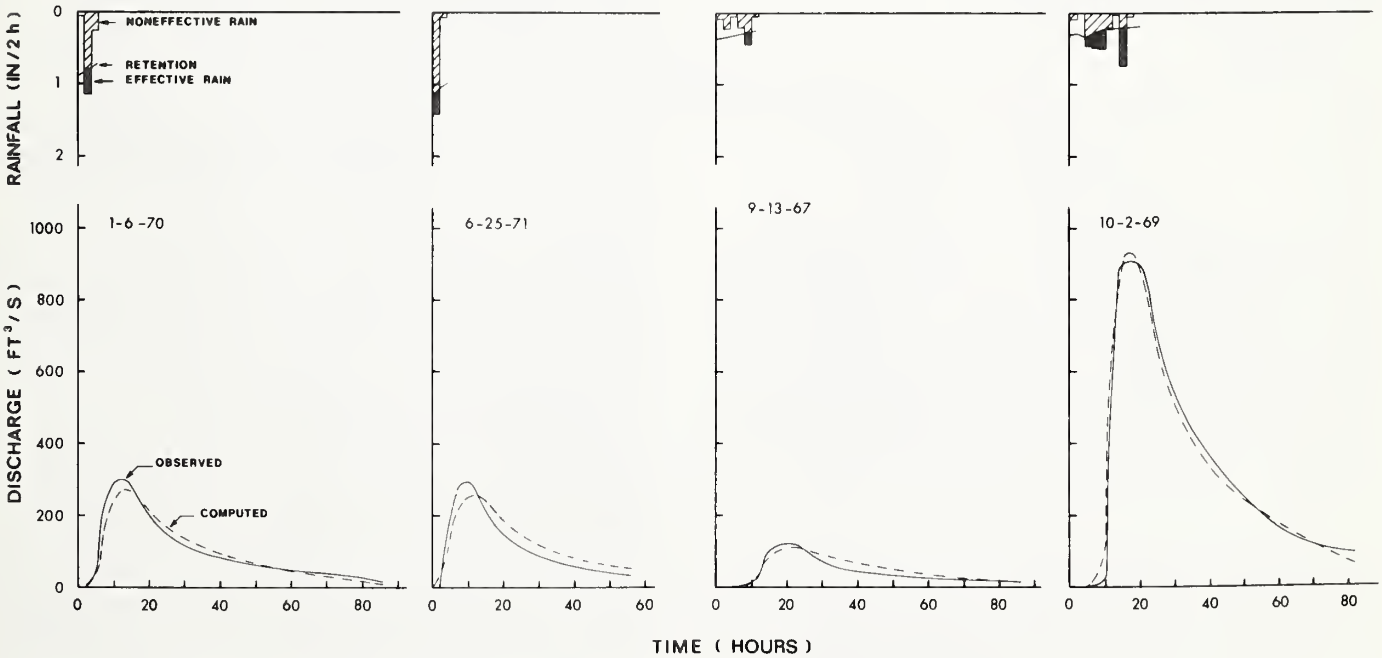

FIGURE 5.27.—Computed and observed hydrographs, subwatershed W-3 after channelization.

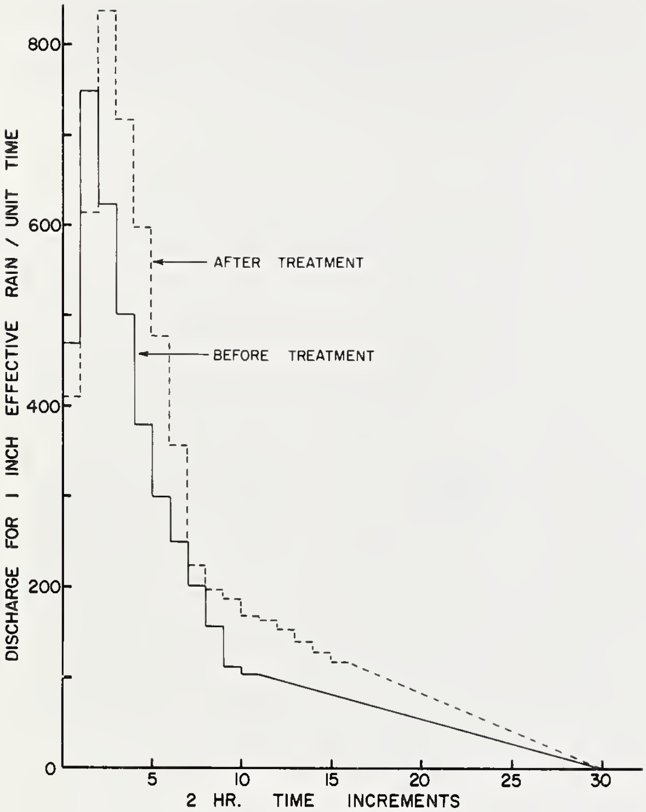

FIGURE 5.28.—Unitized characteristic functions, subwatershed W-3 before and after channelization.

Effects of channelization.—A discussion of the effects of channelization on storm-hydrograph model parameters was given in section 5.2.1 with reference to table 5.4. However, it was pointed out that storm differences affect parameter values, and comparisons of parameter values do not adequately reflect true treatment effects, especially with the change in watershed area. Use of information in table 5.4 will be demonstrated by predicting storm hydrographs from synthetic rainfall input. Two rainfall patterns, each with a wet and a dry antecedent condition, were used with before-treatment and after-treatment model parameters. Four hydrographs were generated for each treatment.

Rainfall for two events was stochastically generated with the procedure discussed in section 4.1.4. Parameters of the hydrograph model were set to the numerical values given in table 5.4. Initial value of retention was set to 0.70 inch per hour for dry antecedent conditions and to 0.20 inch per hour for wet antecedent conditions. Eight simulation runs were made as follows:

Period	*Synthetic storm No. 1*		*Synthetic storm No. 2*	
Before treatment	Dry	Wet	Dry	Wet.
After treatment	Dry	Wet	Dry	Wet.

Output from the hydrograph simulation included average retention for each time increment, effective rainfall for each time increment, and the calculated hydrograph. Rainfall histograms, retention functions, and calculated hydrographs are shown in figure 5.29. Before- and after-treatment values are shown on each of the four plots for direct comparisons of differences. The first rainfall pattern was an advanced storm with a delayed secondary burst. The before-treatment retention parameters resulted in effective rainfall during the secondary burst, whereas the after-treatment retention parameters did not result in effective rainfall during the secondary burst. The after-treatment parameters resulted in a sharper hydrograph with a higher peak that occurred earlier than did that for the before-treatment parameters. Basically, the difference in runoff volume was the amount of effective rainfall in the secondary burst.

The second plot in figure 5.29 has the same rainfall pattern as the first plot but with wet antecedent conditions. Again, the after-treatment peak was in advance of and greater in magnitude than the before-treatment peak. Despite the additional runoff volume caused by the increased area, there is less difference in volume of effective rainfall, as can be seen by the close agreement of retention values for the treatment periods. The second rainfall pattern was a delayed storm that built up uniformly to a maximum and then dropped off uniformly. The third plot shows a reversal of treatment effects under dry conditions; i.e., the peak for the before-treatment parameters is much larger with a significantly greater volume of streamflow, which is shown by the respective hydrographs and retention functions. The peak for the after-treatment parameters occurred earlier than did that for the before-treatment parameters. The fourth plot shows the results of simulation from the second storm pattern with wet antecedent conditions. Again, the effective rainfall volumes are very similar, as indicated by the retention functions. However, storm runoff volume does differ because of the difference in before- and after-treatment drainage areas. The after-treatment parameters resulted in a higher peak that occurred in advance of that for the before-treatment parameters.

The four sets of hydrographs show that watershed channelization and associated water-level control structures do

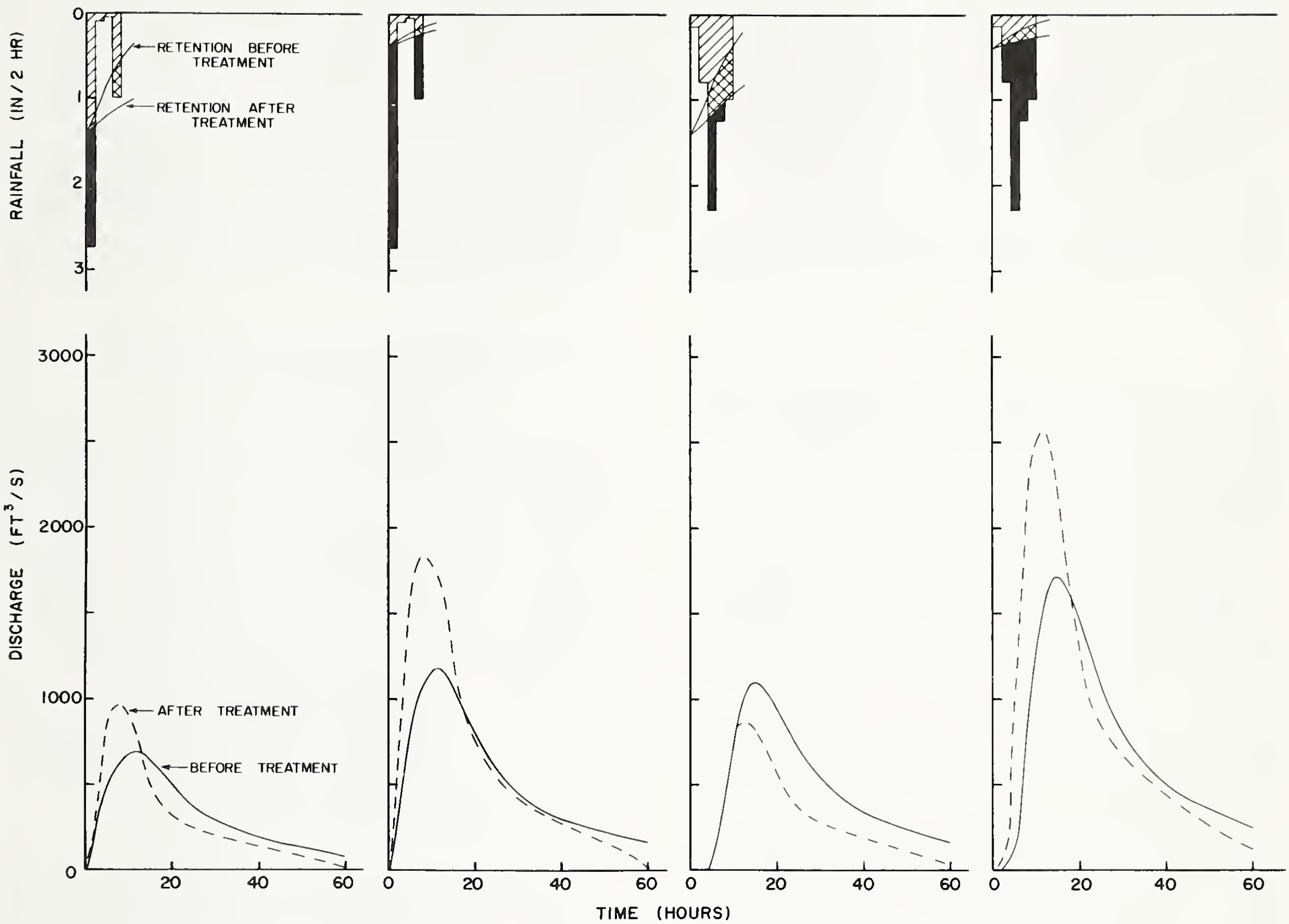

FIGURE 5.29.—Simulated hydrographs from synthetic rainfall events, subwatershed W-3.

not cause totally consistent results, so blanket cause-and-effect statements cannot be made. Rainfall pattern, both distribution and timing, have major effects on streamflow response. Optimized parameter values can be biased by selection of storms for analysis. This makes the storm analysis no less valid, since a spectrum of storms was selected and, in fact, supports the thesis of simultaneous multiple-storm analysis to provide an averaging over varied conditions. Hydrograph generation, using optimized parameter values and the synthetic rainfall data, also reveals the nonlinearity of the system. The two initial retention values for each storm pattern show the differences in retention and hydrograph shape (fig. 5.29). This is particularly true for the last two sets of computed hydrographs, which exhibit vastly different magnitudes and a reversal of relative peak discharges for the before- and after-treatment conditions.

There are two features of the generated hydrographs that should be noted. In all four plots, the after-treatment hydrograph peaks come earlier than those for before treatment. Secondly, the discharge recedes more rapidly for after-treatment conditions. These two characteristics are desirable from the drainage viewpoint; i.e., the rapid removal of flood waters reduces the potential for drowning vegetation and reduces the threat of damaging floods from successive storms. In the presentation of the state function in section 5.2.1, the effect of discharge at the beginning of a time interval on the function was given by equation 5.12, the term WQ_t/DA. An example of this effect might be shown imaginatively with the third set of hydrographs in figure 5.29. If a secondary storm event occurred, beginning 40 hours after the start of the depicted storm, the discharge rate for after-treatment conditions would be 190 cubic feet per second as compared

with 340 cubic feet per second for before-treatment conditions. The net difference of 150 cubic feet per second would make appreciable difference in the routed effective precipitation, and the result would be a much greater hydrograph peak for before-treatment conditions. This would be further exaggerated if the secondary storm occurred at 20 hours, when the after- and before-treatment hydrographs show 560 and 930 cubic feet per second, respectively. Although multiple-peak storms were not analyzed in section 5.2.1, the relative effects can be visualized.

Another facet shown in figure 5.29 is the relative storm-runoff volumes for the treatment conditions for all storms. The same initial retention values were used for the before- and after-treatment conditions. This may or may not be realistic, since continuous simulation and accounting of water may result in higher initial retention values for after-treatment conditions. This facet has not been explored and should be considered before blanket statements are made about storm-runoff volumes under the different conditions. All that can be said after analyzing figure 5.29 is that, for the same initial retention, less effective precipitation occurs with after-treatment conditions. The difference in shape factors of the retention (table 5.4) is exhibited in figure 5.29. A physical interpretation of this difference must draw on the ground-water duration analysis of section 4.3.2.1. Wells 1 and 2 were within subwatershed W–3. Although the wells were in different marine terraces, the relative durations were similar in shape for the before- and after-treatment periods. Depths of ground water were greater after treatment for up to about 40 percent of the time, this time being some finite time after storms. This would indicate wetter soil conditions during successive storm events and thus lower initial retention values and relatively greater runoff volumes. At a depth to ground water of approximately 2.5 feet the duration curves of figures 4.36 and 4.37 meet, thus indicating about equal initial retention values. The storm selection criteria for hydrograph analysis (sec. 5.2.1) may have resulted in isolated storms when initial conditions were relatively dry after treatment. The higher value of the minimum retention parameter after treatment (table 5.4) would indicate a drier condition, thus affecting the shape parameter. These differences appear logical. However, such conditions can change drastically for more frequent successive storms and result in more retention in the first storm but less retention in succeeding storms (lower initial retention and more runoff).

These factors are all important in ascribing cause and effect. Opponents and proponents of channelization and water-level control structures should be aware of these factors to fully understand all ramifications of the system. Still another factor must be included for consideration: evapotranspiration. When more water is retained in the soil profile during a storm, the water table will be higher and daily evapotranspiration will more nearly approximate potential evapotranspiration. Evapotranspiration analysis is presented in section 5.4.

5.2.2.—Ground-Water Response to Precipitation

5.2.2.1.—Ground-Water Fluctuations

Ground-water observation wells were located at rain-gage sites in Upper Taylor Creek watershed for convenience of maintenance rather than on the basis of geology. Although the wells did not provide adequate coverage or representation, they were representative of the three geomorphic features in the watershed. Wells 1 and 4 (fig. 1.3) were located in the Penholoway Marine Terrace at a ground-surface elevation of 65 feet above m.s.l. Well 2 was located in the lower-lying Talbot Marine Terrace at a ground-surface elevation of 45 feet above m.s.l. The remaining wells, with ground-surface elevations of approximately 35 feet above m.s.l., were located in the near-shore region of the Pleistocene Pamlico Sea.

Ground-water fluctuations were different at each well. All wells showed some degree of diurnal fluctuations, although the amplitudes for most wells were less than 0.01 foot. Well 1 was a definite exception when depths of water below ground surface were less than 3 feet. Below the 3-foot depth, well 1 exhibited little noticeable diurnal fluctuation (figs. 5.30 and 5.31). Well 1 had negligible diurnal change but responded to precipitation about 2 hours after rainfall began (fig. 5.31). Well 2 did not exhibit diurnal change and was not as responsive to rainfall as was well 1. Also, the magnitude of ground-water rise was greater at well 1. Under high-water-table conditions, diurnal fluctuations at well 1 were about 0.3 foot in amplitude (fig. 5.31). Even under the high-water-table conditions, well 2 did not show diurnal changes. Both wells responded to rainfall within about 2 hours after the beginning of rainfall. The amount of rise was not as pronounced at either well as it was for low-water-table conditions. Although well 4 exhibited some diurnal fluctuations, the amplitude was not nearly as great as that for well 1. The characteristics of wells 3 and 5–7 were very similar to those of well 2.

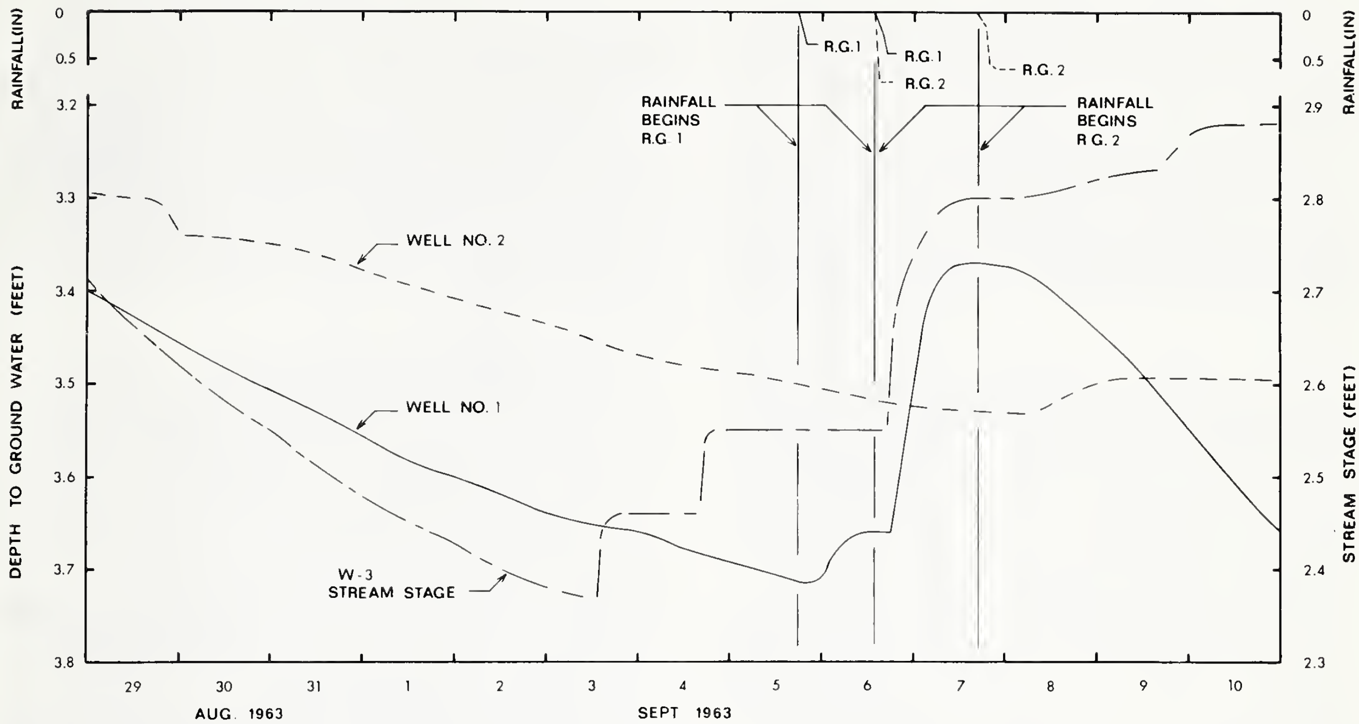

FIGURE 5.30.—Ground-water and stream-stage response to rainfall, low-water-table conditions. (R.G., rain gage.)

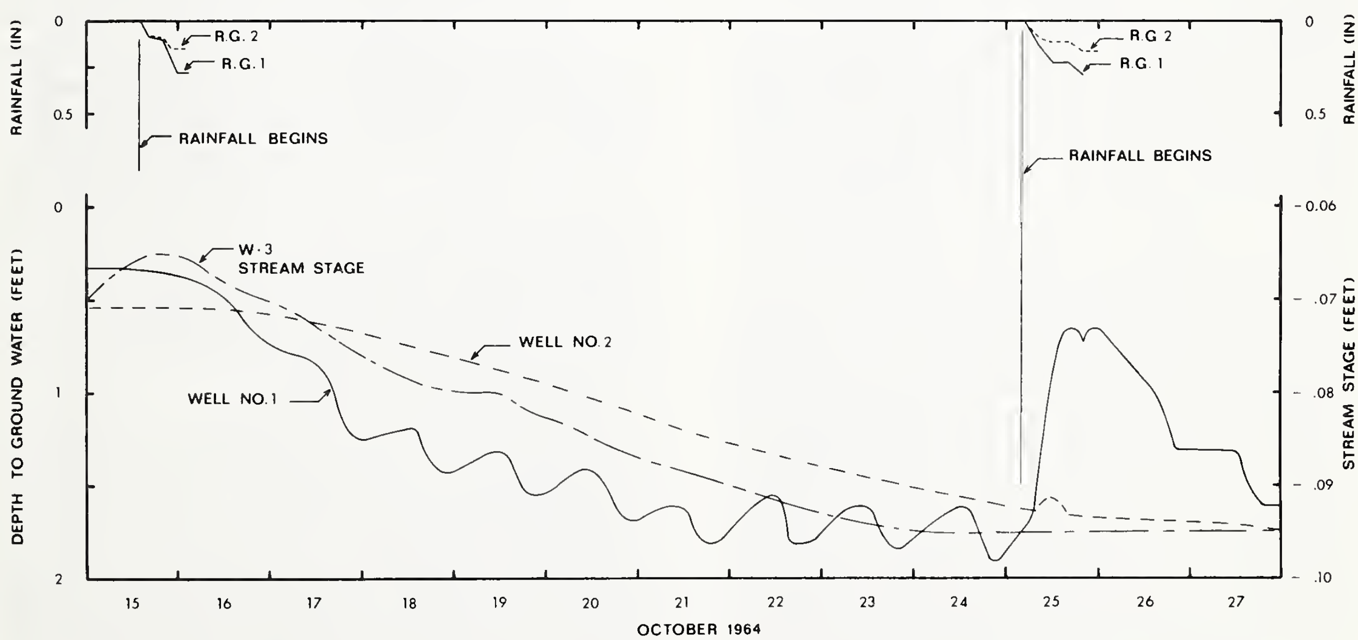

FIGURE 5.31.—Ground-water and stream-stage response to rainfall, high-water-table conditions. (R.G., rain gage.)

Streamflow response to precipitation is also shown in figures 5.30 and 5.31. Stream stage responded at about the same elapsed time after beginning of rainfall on September 6 as did the ground-water level in well 1 (fig. 5.30). Earlier stream-stage response on September 3 and 4 was probably caused by changes in upstream irrigation rather than by rainfall. In October 1964, stream stage did not increase with rainfall but flattened out, probably because of atmospheric changes and associated change in evapotranspiration (fig. 5.31).

A cursory examination of rainfall and ground-water data was made to determine if relationships possibly exist in timing of rainfall occurrence and ground-water rise and peak, especially as related to season. Two years of records for all wells were searched for all well-defined ground-water hydrographs. Lag time between beginning of rainfall and beginning of ground-water rise, amount of rainfall and rise, and lag times between end of rainfall and well hydrograph peaks were tabulated. Depths to ground water at the beginning of rise were also tabulated to determine if depth to water table was a factor in timing or amount of rise, or both. Ground-water response to rainfall exhibited a wide spectrum of results. There was considerable difference between wells as would be expected from the foregoing comments and analyses of data in figures 5.30 and 5.31. The data were tabulated individually for each well and collectively for all wells. Rainfall pattern was not considered, although this obviously has an effect on lag times. For example, an intense advanced storm, in which rainfall stops abruptly at the end, would be expected to result in a rise in ground-water immediately after beginning of rainfall and reach a peak shortly after rainfall ended. On the other hand, a delayed storm may not result in ground-water rise until well after the beginning of the storm. Also, long continued light rain after some previous heavy burst may result in a peak that occurs at or before the end of rainfall. A review of the data revealed all possible combinations. The amount of ground-water rise related fairly well with amount of rainfall, but this too was affected by amount of streamflow; thus well-defined relationships could not be developed. Plottings of these data produced scatter diagrams that varied from well to well, depending on porosity, etc. Lag times between beginning of rainfall and beginning of ground-water rise varied considerably, depending on depth to the water table, rainfall temporal patterns, etc., as discussed above. Recorded gage inaccuracies were also a factor in determining lag times. The lags ranged from zero to 11.5 hours for well 1, with a median lag time of approximately 1 to 2 hours. Lags for some wells lasted up to 14 hours, but again the normal lag time appeared to be about 1 to 2 hours. The time to peak after end of rainfall was more variable, ranging up to 24 hours for well 1 and as much as 2.5 days for well 3. Again, there were no well-defined relationships. The many interactions precluded developing of individual relationships. We thought that some model structure should be investigated to provide an analytical technique for the interrelationships. This approach is taken in the next section.

5.2.2.2.—Ground-Water Hydrograph

We conceptualized a ground-water hydrograph model to analyze the interactions among rainfall amount, rainfall pattern, depth to ground water, and amount of ground-water rise (unpublished data). The utility of any model is to ultimately link with other models in the generation of an overall system. A ground-water model is not an end in itself; it must ultimately be linked with a storm hydrograph model to produce a water-resource system. It is easier to check such systems in parts rather than as a whole. Since the storm hydrograph model presented in section 5.2.1 was developed and proven successful in analysis and simulation models, it followed that a ground-water hydrograph model should be structured along similar lines with similar or analogous components. A schematic of the model concept is shown in figure 5.32.

Model structure.—The model is actually composed of three components, although only two are shown in figure 5.32. The components are parametrically defined, and the parameters are numerically evaluated, as discussed later. The first component (not shown in figure 5.32) is the retention component to determine rainfall effective for ground-water recharge. As discussed later under "Selection of events for optimization" in this section and in the section on storm hydrograph and ground-water hydrograph simulation (section 5.2.3), the retention as evaluated in the storm hydrograph model will determine effective ground-water recharge.

The characteristic function was conceptualized as a step function defined on a set of four parameters, as shown in figure 5.33. These parameters outline a boundary of the steps. Cursory examination of ground-water records revealed two ground-water hydrograph features: (1) sharp rise with narrow peak and relatively rapid recession, and (2) sharp rise rounded off to a delayed peak and sluggish recession. To conceptualize a function for these conditions, we developed the parameter characteristics function. Parameters $CP1$ and $CP2$ are ordinates of the function

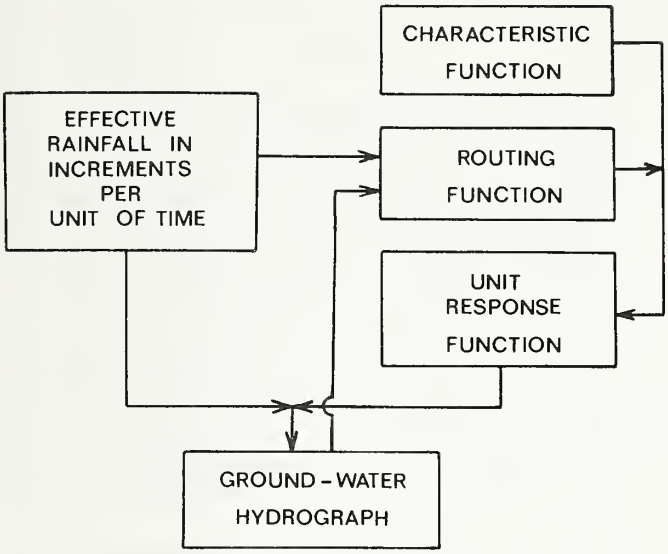

FIGURE 5.32.—Schematic of model for ground-water hydrograph analysis.

with respective times of *CP*3 and *CP*4. Each serves as angle points of the function with linear interpolation between points. In this analysis, a time increment of 2 hours was selected, and a fixed position of zero ordinate value was assumed at 40 time intervals after the beginning of the storm. The characteristic function is a depth-distribution function that can be regarded as the time transform of potential ground-water recharge. After construction, the histogram must be rescaled to equal 1 inch of depth. The function is somewhat analogous to a unit hydrograph with a flattened tail to represent the sluggish late-recession characteristic.

Knisel (*25*) showed that response of a karst ground-water aquifer was approximated by a linear system. Uniform aquifers probably respond linearly; i.e., effective rainfall moves through the mantle to the water table, and discharge from the aquifer is directly proportional to the storage. However, if a soil profile, through which recharge moves, is layered or is otherwise nonuniform, the system may be nonlinear. In the conceptualization of the ground-water hydrograph model presented here, the opportunity for nonlinearity was built in so that linearity would be a unique solution. A function was assumed to represent a state of wetness of the profile to route rainfall through the profile. The function was assumed to vary with depth to water table below ground surface and water content of that profile above the water table. The water content can also be assumed to be a function of depth to water table, as is shown in section 5.4. Then the state function can be expressed in the expotential form

$$S = Ae^{-A^t} \,, \tag{5.14}$$

where S is the state function value, A is a parameter of shape, t is time, and e is the base of the natural logarithms. The area under the curve of equation 5.14 is mathematical unity, required by continuity of mass, such that routing the characteristic only changes its shape and not its enclosed area.

For discrete convolution by time increment, it is necessary to use discrete portions of the state function that are area increments of the function by time increments, computed as

$$S_{t,t+1} = \exp\,(-tA_t) - \exp\,[-(t+1)A_{t+1}]. \tag{5.15}$$

The parameter A is calculated during each round of optimization by the equation

$$A_t = SP_1 + SP_2 G_{t-1} \,, \tag{5.16}$$

where SP_1 and SP_2 are parameters to be evaluated by optimization and G_{t-1} is the depth to ground water at the end of the previous increment.

Snyder and Asmussen (*43*) used a two-function model to approximate subsurface-flow hydrographs in the Coastal Plain in Georgia. The two-stage convolution method resulted in good agreement between observed hydrographs and hydrographs computed with the model, which included 11 parameters. The two-stage convolution provided nonlinearity in the model.

Parameter optimization.—The ground-water hydrograph model outlined above is based on six mathematical parameters that are determined empirically. Values of the parameters can be expected to vary somewhat from storm to storm because of errors in recording instruments and differences between true rainfall and measured rainfall.

A computer program was written to determine parameter values from several storms simultaneously. The program searches for best values of all the parameters until the squared differences between the computed and observed ground-water ordinates for all storms are minimized simultaneously. The procedure, analogous to that for storm hydrograph analysis, provides a smoothing effect

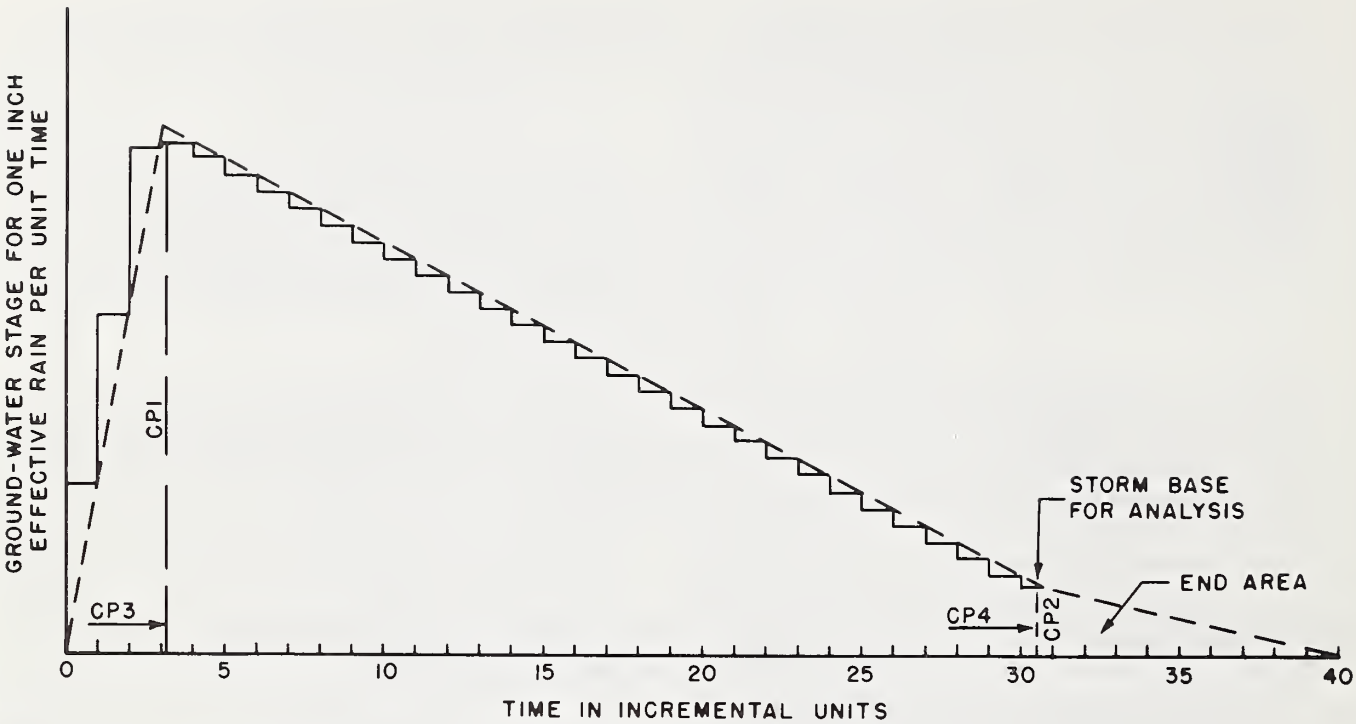

FIGURE 5.33.—Ground-water characteristic function.

and gives the optimum fit overall instead of an optimum fit for any individual storm.

Some difficulty was encountered when analyzing ground-water data. The data were recorded as depth to ground water below the land surface such that an increase in depth represented a decline in water-table elevation; i.e., use of the values directly would indicate increased ground-water storage when the water table was actually receding. One way to circumvent this problem was to convert depth to ground water to m.s.l. elevation by subtracting depths from ground-surface elevation. However, this procedure resulted in a small range of fluctuations as compared with the absolute value of m.s.l. elevation. An alternate method, which proved satisfactory in this analysis, consisted of subtracting the depth of ground water from an arbitrarily small number, 10 in this case. The absolute fluctuations of the ground-water depths in Upper Taylor Creek watershed were approximately 6 feet, so a value of 10 was usable.

Selection of events for optimization.—As stated above, it is easier to test system submodels in parts rather than as a whole. One means of testing the ground-water hydrograph model concepts is by selecting storms in which all storm rainfall is effective in recharging groundwater, and thus increased streamflow for some finite period is, for all practical purposes, negligible. Basically, this was the criterion for selection, with a further constraint that at least 2 days without rainfall preceded the event and at least 3 days without additional rainfall elapsed after the event. Short-duration rainfall events and a wide range of antecedent conditions would test the linearity of the system, as explained in the description.

In the initial phases of the analysis, ground-water elevations for wells 1 and 2 were weighted as for rainfall to approximate a watershed water table. The characteristic behavior of the two wells, as explained in section 5.2.2.1, was drastically different, and averaging for them resulted in hydrograph distortion. We deduced that a better approximation of a watershed water table could be determined in simulation by predicting hydrographs for wells individually and then weighting or averaging. Therefore, the analysis was restricted to well 1. Channelization was shown to be insignificant in affecting ground-water durations (sec. 4.3.2.1), so there was no attempt to separate events before and after treatment. Also, the soil mantle was not altered by channelization; thus, the model parameters would not be expected to change. If chan-

nelization affected ground-water drainage, the routing-function parameters would change.

As in the case with storm hydrograph selection, instrument malfunction resulted in a minimum of usable events. The criterion that increased streamflow should be negligible resulted in two conditions: (1) drastic reduction of the total number of storms, and (2) reduction of the range of antecedent ground-water depths. The hydrology of south-central Florida is somewhat unusual in that significant runoff occurs only when the water table is at or near the ground surface and the soil profile can absorb little additional rainfall. The soil porosity is such that significant rainfall will raise the water table significantly, and small amounts of runoff will occur. This is especially true of the Penholoway Terrace.

An initial list of approximately 10 storms was screened to eliminate undesirable features, and the screening resulted in only 4 suitable storms for analysis. The storm dates, rainfall amounts, and depths to ground water at the beginning of the storms are shown in table 5.5. All selected storms occurred during the dry season, and the antecedent depths to ground water represent a narrow range of values.

Table 5.5.—Selected storms and associated rainfall volumes and depths to ground water for ground-water hydrograph analysis

Storm date	Rainfall (inches)	Depth to ground water (feet)
Feb. 12, 1963	1.00	2.83
Dec. 27, 1964	.62	1.28
Feb. 2, 1965	.85	2.53
Mar. 27, 1965	1.49	2.67

Results of optimization.—A 2-hour time increment was assumed to be adequate for ground-water hydrograph analysis. This assumption was based on examination of well records and in consideration of the storm hydrograph analysis. Optimized parameter values are shown in table 5.6. The correlation coefficient of 0.937 shows good agreement between computed and observed ground-water hydrographs. Rainfall histograms and computed and observed ground-water hydrographs are shown in figure 5.34. Since selected storms resulted in a negligible increased streamflow, all recorded rainfall was considered as retained in the ground water and thus effective for ground-water recharge. The rainfall patterns were similar for all storms but varied in amounts. Observed hydrographs show some irregularities in shape that cannot be explained, such as that for the storm of 12–27–64. The rainfall pattern would indicate a smooth, rounded hydrograph, but observations showed irregularities across the peak as well as on the recession. Recorder malfunctions may have occurred that indicate nonuniformity, when actually a smooth hydrograph may have occurred. Also, as was shown earlier, for shallow depths to ground water, well 1 exhibited considerable diurnal fluctuations. Diurnal effects superimposed on the hydrograph would result in distorted hydrographs.

Table 5.6.—Optimized values of parameters and correlation coefficient for ground-water response model

Well No.	Characteristic function parameters[1]				State function parameters		Correlation Coefficient
	CP_1	CP_2	CP_3	CP_4	SP_1	SP_2	
1	3.302	0.688	3.618	33.64	0.121	0.235	0.937

[1]See figure 5.37.

A characteristic flattening of the observed hydrographs occurs late in the recession. The model concepts appear capable of approximating the recession shape. The ability of the model to approximate the rapid rise that occurred during the 1963 and 1965 storms lends to the validity of the concepts. As was pointed out in the discussion of the storm-hydrograph method, optimization over four storm sets simultaneously results in the best overall fit as opposed to fitting a single storm. The maximum difference between observed and computed hydrograph peaks was about 0.3 foot. In section 5.2.2.1, we stated that the amount of rise versus rainfall amount varied considerably for each well from storm to storm. This variability was greatest for the well used in this section (well 1). The timing of computed peaks agreed fairly well with observed peaks.

The unit-response functions for each time increment for all storms were very nearly identical, thus indicating a high degree of linearity of the ground-water system. Further testing of the model is needed, but, at least for Upper Taylor Creek watershed ground-water conditions, a linear system is sufficient. A unit hydrograph can be derived, and application should result in a good approximation of the system response. Results of the hydrograph modeling and analysis are encouraging with respect to future analyses and potential of the method; the concepts appear valid.

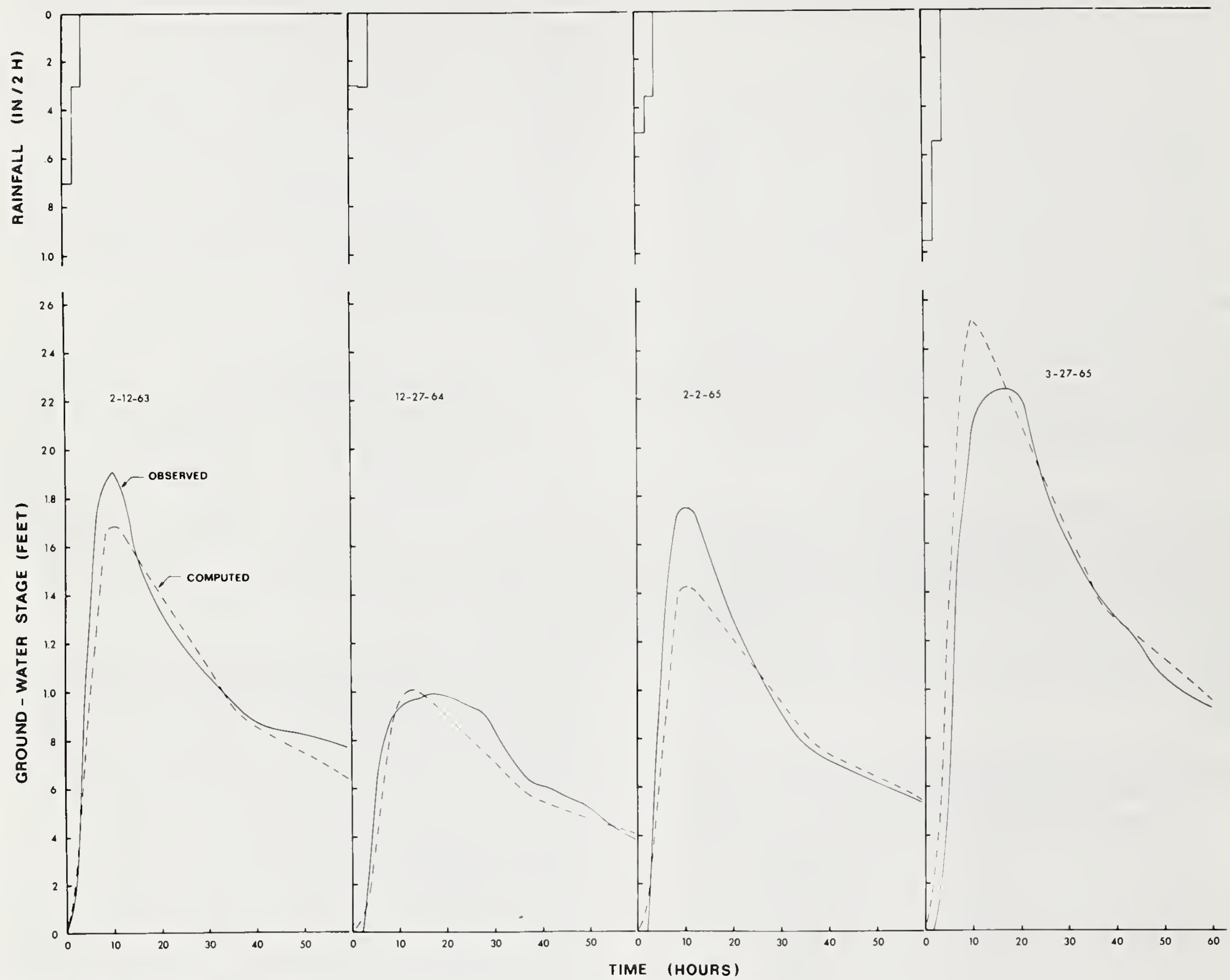

FIGURE 5.34.—Computed and observed ground-water hydrographs, well 1.

5.2.3.—Streamflow and Ground-Water Simulation

In sections 5.2.1 and 5.2.2.2, storm hydrograph and ground-water hydrograph models were presented as individual components. It was stated that model construction was similar in concepts and structure. It was further pointed out that the retention function of the storm model determined rainfall effective for streamflow and that the remaining rainfall was retained in the profile for ground-water recharge. In this section, the two models are linked together for combined streamflow and ground-water simulation.

Figure 5.35 is a schematic drawing of the combined streamflow and ground-water models. The linkage between the two components occurs at the retention function, or the initial partitioning of rainfall. The calculated retention is effective for ground-water recharge, while the rainfall excess to retention is effective for storm-hydrograph generation. Because of the similarity of submodel structures, the two sides of the schematic are basically mirror images.

A streamflow and ground-water simulation program was developed, and a historical storm event was selected for testing the models. The selected storm event was not used

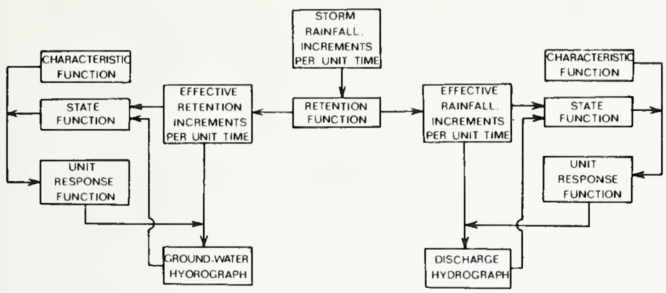

FIGURE 5.35.—Schematic of model for discharge hydrograph and ground-water hydrograph simulation.

in either the storm hydrograph analysis or ground-water hydrograph analysis, but the event was one in which significant streamflow and ground-water rise occurred. Observed rainfall, observed antecedent streamflow at the beginning of the storm, and estimated initial retention were used as input along with optimized parameters determined from analysis in sections 5.2.1 and 5.2.2.2. The resultant streamflow and ground-water hydrographs were computed and are shown in figure 5.36. Observed hydrographs are also shown for comparative purposes. As stated in section 5.2.1, the initial retention was adjusted externally in hydrograph analysis. In the simulation, the first estimate of initial retention resulted in overprediction of streamflow volume by approximately 25 percent and, consequently, an underestimate of the ground-water recharge. The initial retention was not adjusted after the simulation run, but rather the resultant hydrographs are shown in figure 5.36 to give the reader an idea of what can be expected on first trial. The calculated hydrographs differ considerably from the observed hydrographs both in peak magnitude and peak timing. Section 5.2.2.2 stated that ground-water hydrograph selection for analysis was made such that negligible storm runoff occurred. Depths to groundwater at the beginning of the selected events were in the order of 2 to 3 feet. The storm selected for simulation had an antecedent depth to ground-water of 2.35 feet, but the rainfall accumulation resulted in about 1.7 feet of rise, and runoff occurred. Also, we pointed out in section 5.2.2.1 that well 1 exhibited considerable diurnal fluctuations when depths were less than about 2.5 feet. Such fluctuations make it difficult to accurately describe the well record from the chart. Some of the differences between the calculated and observed ground-water hydrographs in figure 5.36 may be caused by these fluctuations.

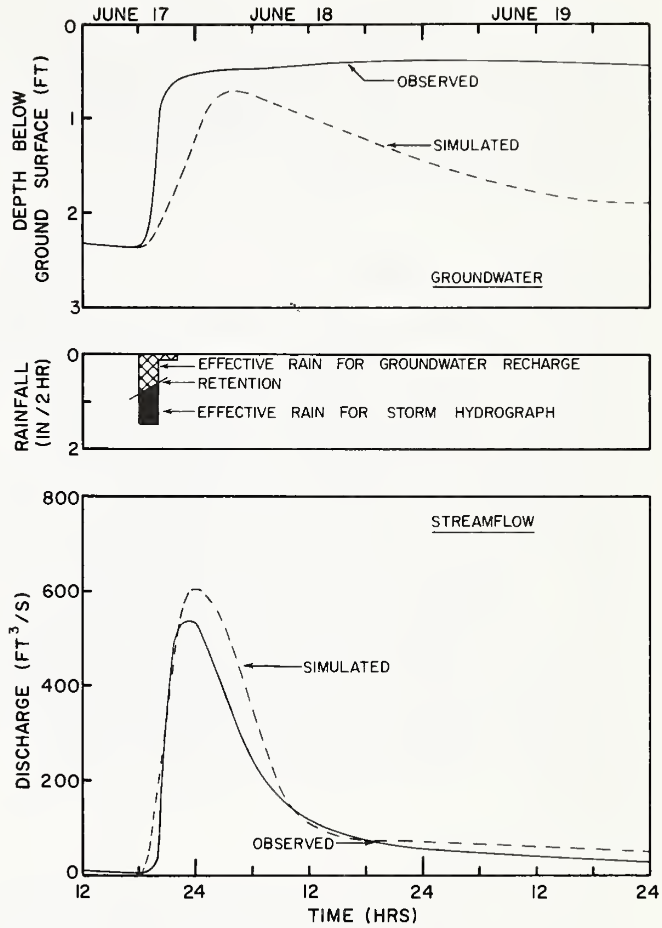

FIGURE 5.36.—Simulated storm and ground-water hydrographs, subwatershed W-3 and well 1, storm of June 17, 1971.

Ground-water hydrographs selected for model-parameter optimization generally indicated more rapid recessions than that shown for the observed hydrograph for the storm of June 17, 1971. Examination of ground-water and streamflow records revealed that when direct runoff occurs, ground-water recessions are slower than for equivalent recharge without runoff. This indicates that the ground-water model parameters may be biased by storm selection for more rapid recession than actually occurs when there is runoff.

The overestimation of streamflow volume resulted from the underestimation of initial retention. This indicates that accurate estimates of initial retention are needed to give good agreement between storm hydrographs and ground-water hydrographs. A relationship between initial retention and antecedent rainfall, or depth to ground-water, is needed to improve the predictive techniques described.

In spite of the differences between simulated and observed hydrographs, it has been demonstrated that the conceptualized streamflow and ground-water hydrograph models are valid. Also, the simulation techniques, using observed or synthetic rainfall data, result in the right order of magnitude for computed values.

5.3.—Recession Analysis

During periods between rainfall events, water users must rely on water captured and stored during precipitation events or water from deep ground-water storage. Much water may be stored as shallow ground water, which serves as the source or supply for streamflow during recession periods. The ability to predict the quantity and dependability of this water supply during streamflow recession periods is of great value to the farmer or other water user. Estimates of recession characteristics will facilitate the forecasting of allowable withdrawals from streams for irrigation or pollution abatement. One method of predicting streamflow during recessions was developed by Yates and Snyder (*63*) and found to be accurate and dependable in channels of the North Carolina Coastal Plains. This technique has since been applied to Taylor Creek data.

5.3.1.—Streamflow

According to Yates and Snyder (*63*), streamflow hydrograph recessions normally concave upwards and trend asymptotically toward zero flow, while incremental rates or volumes of flow descend exponentially. The volumetric recession may therefore be written as

$$V_t = V_1^{-bt}, \tag{5.17}$$

where V_t is the mean daily flow volume in cubic feet per second at time t, V_1 is the mean daily flow volume in cubic feet per second at beginning of recession, b is a parameter that controls the shape of the exponential recession, and t represents a later time.

We have arbitrarily chosen to measure discharge as mean daily volumes in cubic feet per second; however, any desired volume and time unit may be readily substituted.

Convolutional techniques involving six parameters are utilized. The first parameter, b, is defined as a routing function that is convolved with a characteristic function to produce daily runoff volumes. Ordinates of the charac-

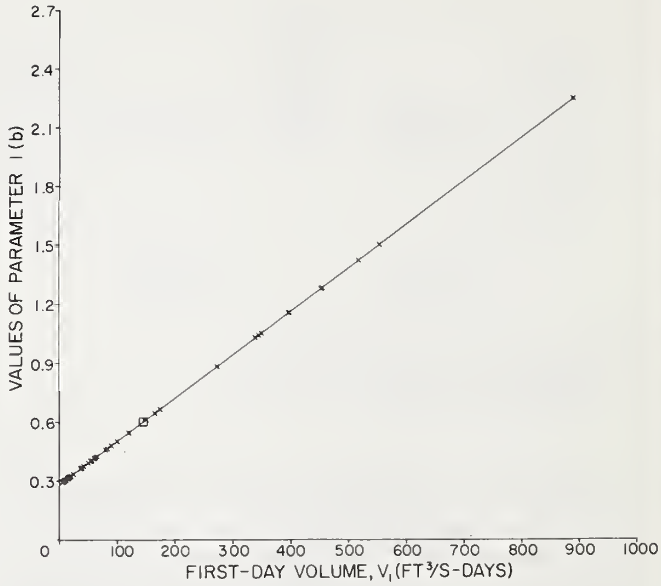

FIGURE 5.37.—Parameter b versus first-day volume V_1, watershed W-2.

teristic function are defined by the remaining five parameters. Parameter values are determined by optimization technique, as reported by DeCoursey and Snyder (*11*). In our optimization of parameter values, we selected recessions of a minimum length of 10 days and a maximum of 29 days. In simulation mode, we again used a minimum of 10 days but placed no limit on maximum time length. As shown in figure 5.37, optimized values of parameter b increase with increasing initial discharge rates. Similarly, figure 5.38 shows that the five optimized parameters used to define ordinates of the characteristic function also increase in value with increasing initial discharge rates. This tendency holds true regardless of size of drainage area. Parameter values are also a function of drainage area size—as drainage area increases, parameter value increases. Therefore, parameter values must be developed and applied specifically for different areas.

A fairly wide range of parameter values occurs for a given initial discharge rate. This must be expected because of variations in such factors as seasonal behavior, antecedent soil-moisture conditions, antecedent channel characteristics, and vegetation. Major problems in Taylor Creek and similar Florida channels that did not exist significantly in earlier North Carolina studies involve flow-control structures and withdrawal of irrigation water from the channel. Both factors create abnormal flow pat-

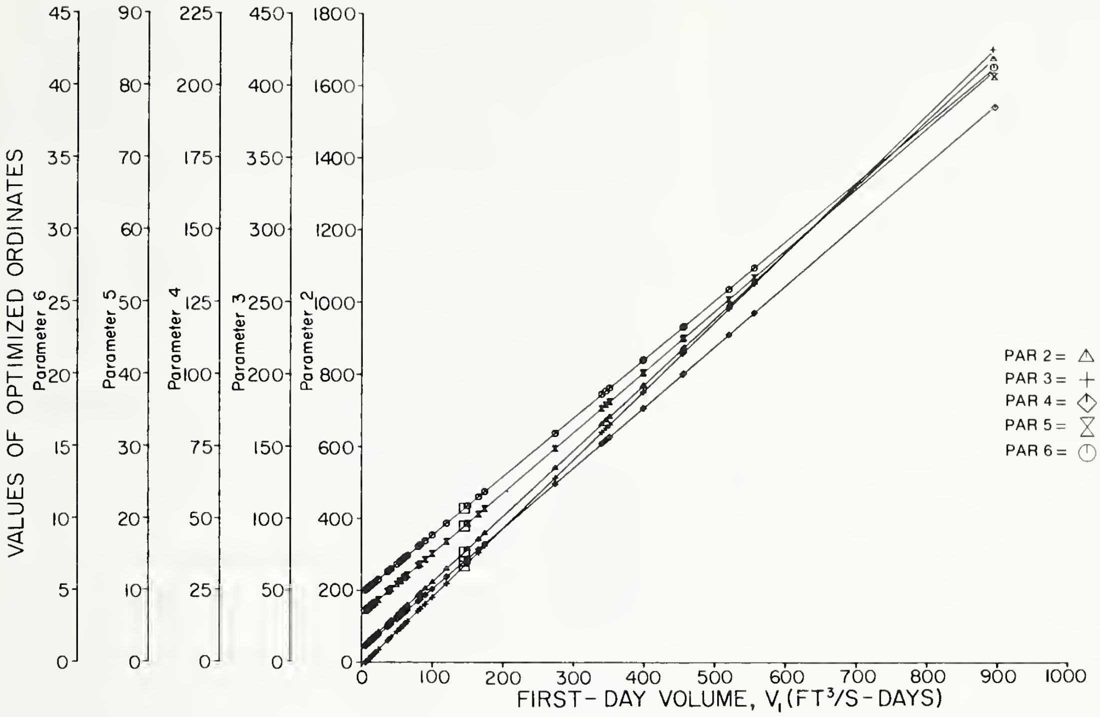

FIGURE 5.38.—Derived values of the five parameter values defining the characteristic function for watershed W-2.

terns within the channel and affect movement of water, both surface and subsurface, from the adjacent drained areas.

Optimized parameter values were used to develop predicted daily flow volumes, which were compared with observed values. For Upper Taylor Creek watersheds W-2 and W-5, average predicted values were 110.5 and 125.4 percent of average observed values. Apparently, further refinement of parameter-value optimization is in order. However, it should be pointed out that percentage errors at low flows were rather high, thereby raising average errors, although volume differences were quite low. At initial flow values of 10 cubic feet per second or less, results were poorest.

Figures 5.39 and 5.40 illustrate the correspondence of calculated volumes and observed volumes for recessions of 13 and 16 days. The calculated values fluctuate around the observed values as expected, since the mathematical computations proceed in a smooth, consistent manner, which may not occur in a natural flow event. However, the daily differences tend to be compensatory, allowing for a reasonable approximation of total flow volume for the entire recession period.

5.3.2.—Ground-Water Recessions

Since ground water is a major source of water for agricultural irrigation, it is only natural that, following a prediction of streamflow recession, some means of determining availability and dependability of ground water is highly desirable. Therefore, the methods developed for streamflow recession analysis were extended to ground-water recession prediction. In ground-water recession analysis, ground-water elevations are used rather than volumes or rates. Difficulties were encountered initially because of the lack of adequate ground-water data.

Using available data, we quickly determined that two major revisions were necessary. First, the use of six parameters allowed excessive degrees of freedom in optimization. Therefore, the number was reduced to four: one for the routing function and only three to define ordinates of the characteristic function. Secondly, there was relatively little difference in maximum and minimum

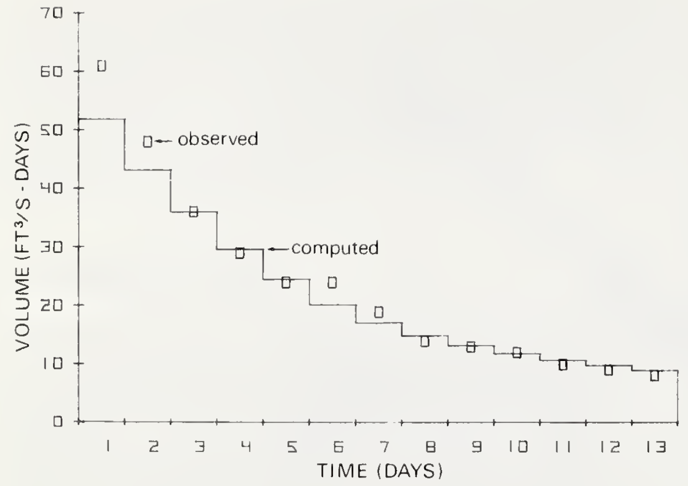

FIGURE 5.39.—Correspondence of calculated and observed volumes for streamflow recession of 13 days, watershed W-2.

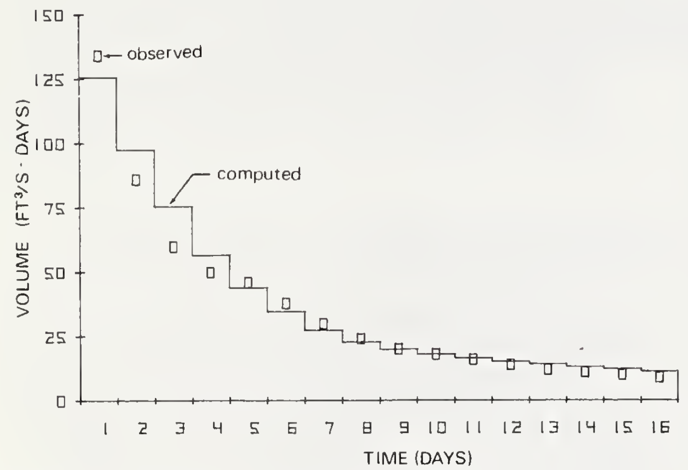

FIGURE 5.40.—Correspondence of calculated and observed volumes for streamflow recession of 16 days, watershed W-2.

ground-water stage values for a given recession, resulting in a recession curve that had little downward slope. This condition was rectified by producing an exaggerated downward slope through use of the equation

$$OBSY(1) = (REFELE - CONST - GHT) \times 10.00, \qquad (5.18)$$

where *OBSY*(1) is adjusted water stage in well in feet, *REFELE* is ground-surface elevation at well in feet, *CONST* is a constant in feet, and *GHT* is gage height in feet as shown on the well stage recorder. Because the stage recorder indicates distance from ground surface to water surface in the well, the observed gage height must be subtracted from the reference elevation (*REFELE*) to determine correct water-surface elevation. Subtracting the constant value and multiplying the result by a factor of 10 allows much greater differential values between beginning- and ending-recession-stage values.

The following example illustrates the procedure. At well 4, ground surface elevation is 65.00 feet. Assuming that the difference in recession stages will not exceed 6 feet, a constant (*CONST*) of 59.00 feet is used (65.00− 6.00=59.00). For a recorded gage height of 0.41 foot at the beginning of the recession, *OBSY*(1)=(65.00−59.00−0.41)×10.00, or *OBSY*(1)=55.9 feet. At the end of the recession, with a recorded gage height of 4.00 feet, *OBSY*(1)=(65.00−59.00−4.00)×10.00, or *OBSY*(1)=20.00 feet. This results in an apparent recession of 35.9 feet, whereas in reality there is a difference of only 3.59 feet. This greater difference in beginning and ending values is necessary for satisfactory optimization.

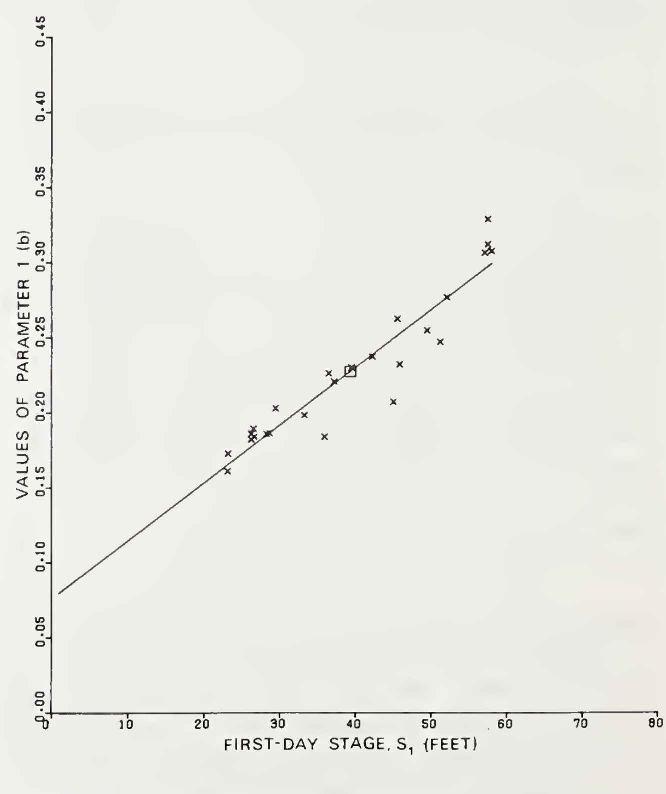

FIGURE 5.41.—Parameter *b* versus first-day stage, S_1, well 1.

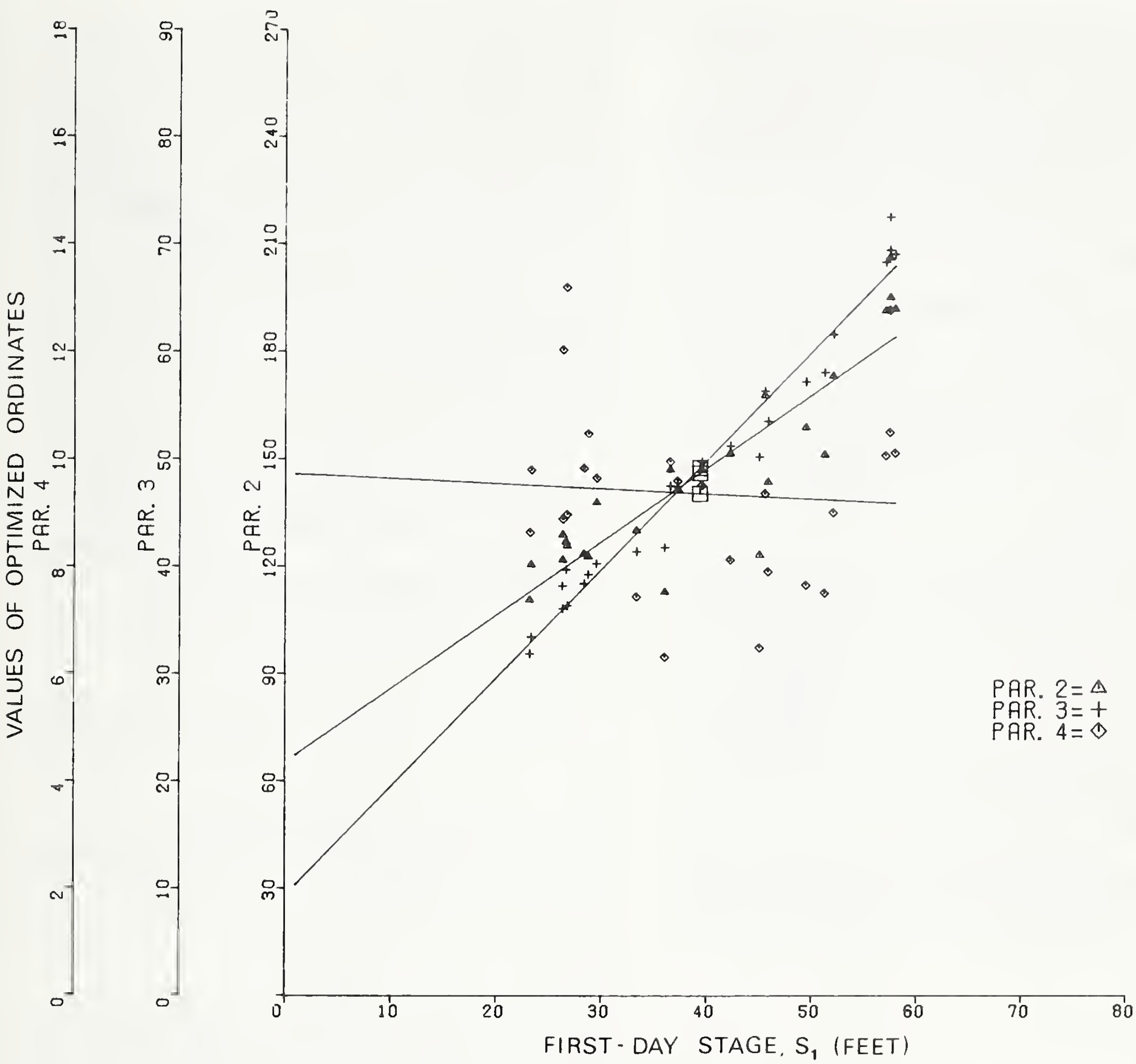

FIGURE 5.42.—Parameters 2, 3, and 4 versus first-day stage, S_1, well 1.

Though all parameter values increased with increasing values of streamflow discharges (figs. 5.37 and 5.38), this trend held true only for the first three parameters of well recession stages (figs. 5.41 and 5.42). Parameter 4 was almost constant but decreased slightly with increasing value of initial stage.

Predicted stage values averaged 109.9 and 90.7 percent of observed values at wells 4 and 7 (figs. 5.43 and 5.44).

5.4.—Evapotranspiration

Evapotranspiration studies are generally made on single crops or land-use cover or in lysimeters (*17, 48*). The studies are often specifically concerned with potential evapotranspiration, especially in humid regions and irrigated areas (*48*). Evapotranspiration from watersheds under natural conditions occurs at potential rates for only a small percentage of time, and it is generally well below the potential rate.

Water-resource plans and hydrologic analyses for large areas generally consider long periods, so changes in ground-water storage can reasonably be assumed to be zero (*27*). This assumption eliminates the need for extensive ground-water observations, and evapotranspiration is equivalent to precipitation minus stream flow.

Evapotranspiration can be expressed as

$$ET=P-Q+GWI-GWO-PERC\pm\Delta GW\pm\Delta SM \quad (5.19)$$

where ET is evapotranspiration, P is precipitation, Q is streamflow, GWI is ground-water inflow, GWO is ground-water outflow, $PERC$ is deep percolation, ΔGW is the change in ground-water storage; and ΔSM is the change in soil-moisture storage.

In this watershed analysis, precipitation, streamflow, and ground-water data were available (sec. 2), but soil-moisture data and well hydraulics were not available. Upland core samples were taken at each of the seven ground-water observation well sites, and laboratory analysis was made to develop composite adsorption and desorption curves (*46*). The curves, shown in figure 5.45, can be used to determine the change in ground-water storage between the beginning and ending of any selected period of time.

The soil associations of Taylor Creek watershed are given in table 1.1. McCollum and Pendleton (*30*) gave ranges

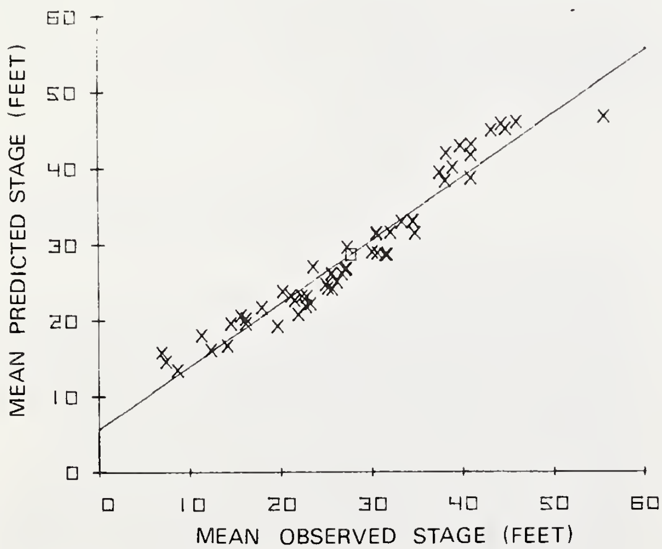

FIGURE 5.43.—Correspondence of calculated and observed values of recession stages, well 4.

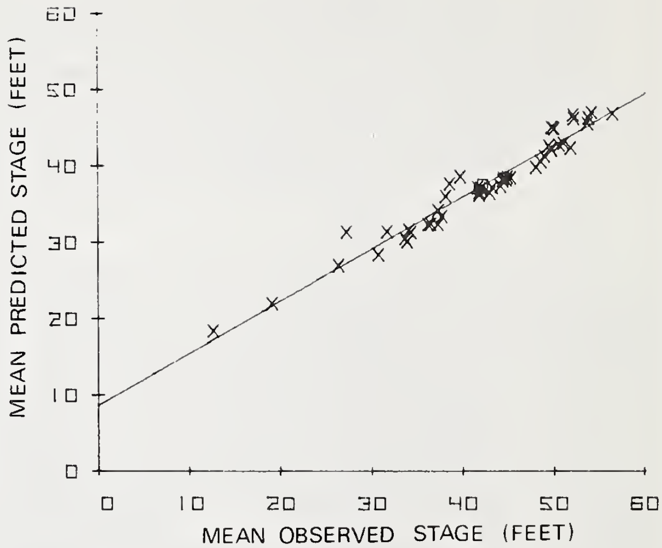

FIGURE 5.44.—Correspondence of calculated and observed values of recession stages, well 7.

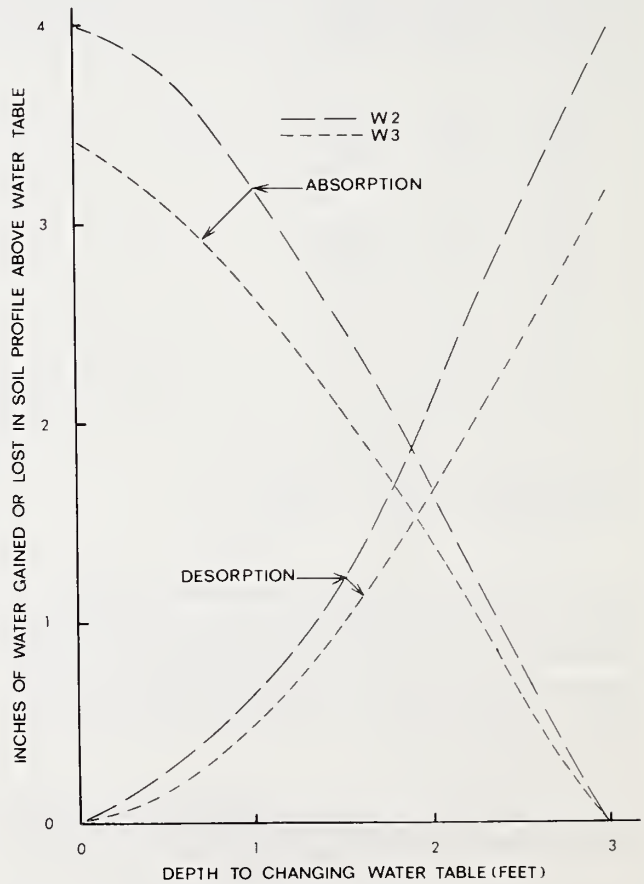

FIGURE 5.45.—Composite moisture absorption and desorption curves characteristic of the soils, watersheds W-2 and W-3.

of available water for each soil type by depth in the profile. These values were weighted by percentage of area to determine the composite wateshed values given in table 5.7 for watersheds W-2 and W-3. Although a 60-inch soil profile is shown in the table, the depth from which evaporation and transpiration takes place is less than 60 inches. Each year the water table fluctuates to near the ground surface and thereby causes root pruning, which results in reduced ability of the plants to withdraw water from the lower depths. The Florida Water Resources Council (FWRC) estimated that rooting depths for citrus in soils of the types found in Taylor Creek watershed ranged from 1.5 to 2.0 feet, and usable water in the root zone ranged from 1.2 to 4.2 inches (*51*). Native trees of the area probably have similar active root zones, and grasses probably have less deep active root zones. The FWRC estimates of usable water are not greatly different from those of table 5.7. From the data in the table, estimates were made, based on depth to the water table, of the capacity of the soils to make up water during rainfall. The following assumptions were made:

(1) When the water table is less than 6 inches below ground surface, 100 percent of the available water is in the profile.

(2) When the water table is between 6 and 12 inches below ground surface, 100 percent of the available water remains in the profile below 12 inches and 80 percent of the available water remains in the profile above 12 inches.

(3) When the water table is between 12 and 24 inches below ground surface, 100 percent of the available water remains below 24 inches, 80 percent remains in the 12- to 24-inch-depth range, and 50 percent remains in the profile above 12 inches.

(4) When the water table is 24 to 36 inches below the ground surface, 100 percent of the available water remains below 36 inches, 80 percent remains in the 24- to 36-inch-depth range, 50 percent remains in the 12- to 24-inch-depth range, and 25 percent remains above 12 inches.

(5) When the water table is 36 to 48 inches below ground surface, 100 percent of the available water remains below 48 inches, 80 percent remains in the 36- to 48-inch-depth range, 50 percent remains in the 24- to 36-inch-depth range, 25 percent remains in the 12- to 24-inch-depth range, and none remains above 12 inches.

(6) When the water table is 48 to 60 inches below ground surface, 80 percent of the available water remains in the 48- to 60-inch depth range, 60 percent remains in the 36- to 48-inch-depth range, 40 percent remains in the 24- to 36-inch-depth range, 20 percent remains in the 12- to 24-inch-depth range, and none remains above 12 inches.

(7) When the water table is over 60 inches below ground surface, 75 percent of the available water remains in the 48- to 60-inch-depth range, 50 percent remains in the 36- to 48-inch-depth range, 25 percent remains in the 24- to 36-inch-depth range, and none remains above 24 inches.

Table 5.7.—Available water in the soil profile as a composite of soils in watershed W-2 and subwatershed W-3

Soil depth	Available water (inches) in— W-2	W-3
Zero to 12 inches	0.90	0.62
12 to 24 inches	.85	.64
24 to 36 inches	.90	.81
36 to 48 inches	.75	.64
48 to 60 inches	.75	.64
Total	4.15	3.35

Assumption 7 probably approaches a minimum of water in the profile under extreme conditions of the Florida climate. These assumptions were used to develop the curves of figure 5.46 for use in estimating the change in soil-moisture storage during a specific period. These data

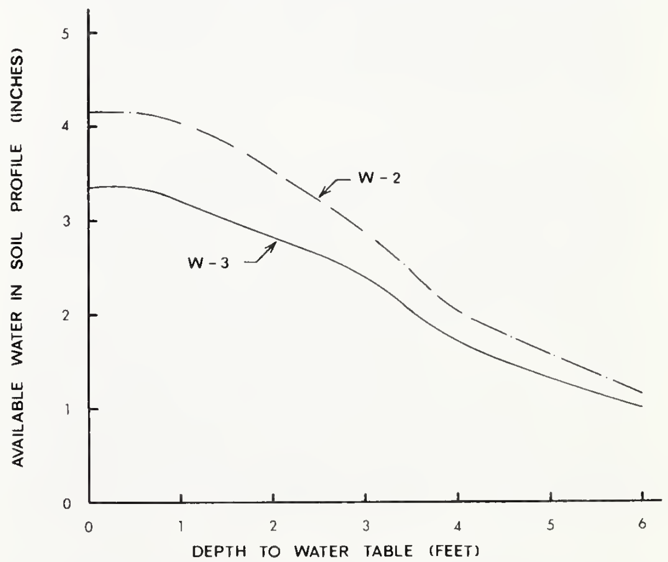

FIGURE 5.46.—Relationship between depth to water table and available water in the soil profile, watersheds W-2 and W-3.

are obviously subjective, but they are in the right order of magnitude and aid in better estimating evapotranspiration for watersheds W–2 and W–3. The data above indicate the significance of the soil-moisture term in equation 5.19.

Geologic investigations in central and southern Florida show a definite aquiclude above the Floridan aquifer (*35*). Irrigation wells were developed in the Floridan aquifer in Upper Taylor Creek watershed, and these wells are under artesian pressure. This is additional evidence of an aquiclude above the aquifer. By definition of an aquiclude, deep percolation is negligible, so the term *PERC* in equation 5.19 can be neglected. Well-hydraulic data were not available for the clastic aquifer in the watershed. Therefore, published data for surrounding areas were used to estimate transmissivity of the clastic aquifer in the watershed. Bearden (*3*) reported a range in transmissivity of 10,000 to 53,000 gallons per day per foot in St. Lucie County. Although these values were not exact and were transposed from an adjoining county, they suffice to show the order of magnitude of the *GWI* and *GWO* terms in equation 5.19.

5.4.1.—Annual Data

We used monthly precipitation, streamflow, and ground-water data for the years 1959–63, before channelization, and 1965–73, after channelization, with the assumptions and transposed data discussed in section 5.4 to determine annual watershed evapotranspiration. The specified periods enable a comparison to be made in order to estimate the effects of channelization and associated water-level control structures.

Water-table contour maps were developed for several dates, with both high- and low-water-table conditions. Although the number and distribution of ground-water observation wells were not adequate to properly define water-table contours in the watershed, maps were developed with the available data. Figures 5.47 and 5.48 are typical of the low- and high-water-table conditions, and they show irregularities that cannot be explained by reasons other than well spacing and arrangement. However, the contours are generally similar to surface topography, and they provide estimates of hydraulic gradient for use in the *GWI* and *GWO* terms of equation 5.19.

In subwatershed W–3, estimated lengths of ground-water inflow and outflow are 6.4 and 4.5 miles for watershed

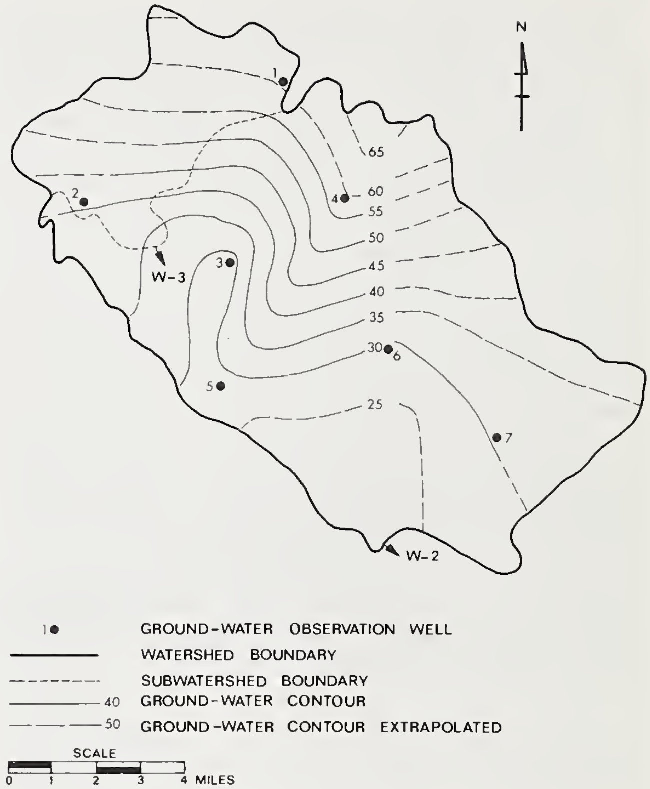

FIGURE 5.47.—Ground-water contours for low-water-table conditions, watersheds W–2 and W–3. (Watershed boundaries before January 1967.)

boundaries before 1967. Estimated inflow and outflow hydraulic gradients are 0.001 foot per foot. The inflow gradient is probably nearer zero, since surface topography, and thus water table, drops off to the north and northeast. The slope of 0.001 foot per foot as a maximum was used in the calculations for inflow. The maximum transmissivity found by Bearden (*3*), 53,000 gallons per day per foot of length of the clastic aquifer, was also used in the calculations. The ground-water inflow or outflow can be estimated by

$$GWI = C\frac{L*D*T*S}{A} \qquad (5.20)$$

where *GWI* is ground-water inflow in inches, *D* is the number of days for the time period of interest, *T* is transmissivity in gallons per day per foot of length of inflow, *L* is the length of inflow in miles, *S* is the hydraulic gradient in feet per foot, *A* is the watershed area in square miles, and *C* is a constant for converting to appropriate units (5.05×10^{-6}). Substituting these values in

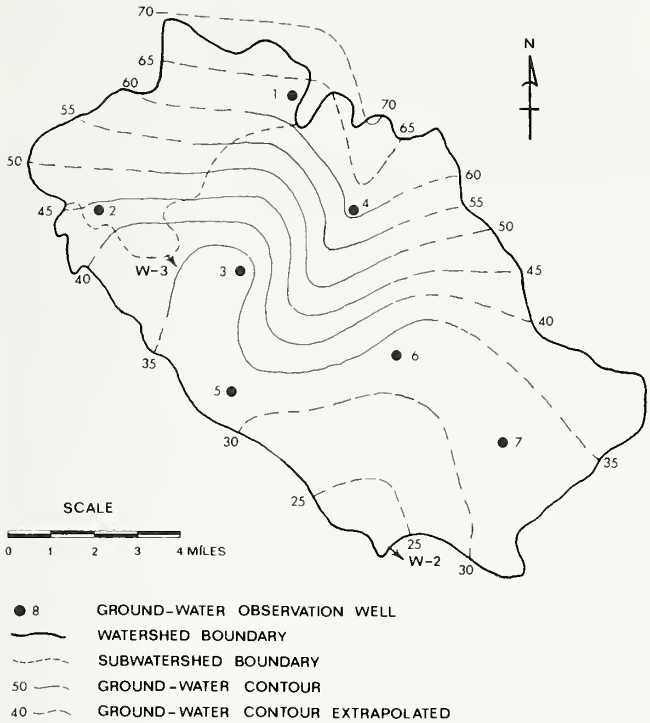

FIGURE 5.48.—Ground-water contours for high-water-table conditions, watersheds W–2 and W–3. (Watershed boundaries before January 1967.)

equation 5.20 gives an annual value of 0.042 inch of ground-water inflow and 0.028 inch of ground-water outflow. The net difference, 0.014 inch of inflow, is negligible. Changes in both W–3 boundaries and W–3 area beginning in 1967 would have no significance net effect, since both L and K increased.

For watershed W–2, the inflow and outflow lengths were estimated from figures 5.47 and 5.48 as 10.0 and 6.5 miles. The inflow and outflow slopes were estimated as 0.001 foot per foot and 0.0007 foot per foot. These values substituted into equation 5.21 give 0.01 inch of ground-water inflow and 0.005 inch of ground-water outflow. Both values and the net difference of 0.005 inch are negligible. Again, changes in W–2 boundaries will have no significant effect.

If the transmissivity and slope values used were in error by 100 percent; i.e., if T should be 106,000 gallons per day per foot and S should be 0.002 foot per foot, the net difference would be 0.05 inch of ground-water inflow for W–3 and 0.031 inch of ground-water inflow for W–2. These estimates of ground-water inflow and outflow are obviously negligible. Therefore, the *GWI* and *GWO* terms, as well as *PERC*, can be dropped from equation 5.19, resulting in

$$ET = P - Q \pm \Delta GW \pm \Delta SM \qquad (5.21)$$

Annual totals of precipitation and streamflow, annual net changes in ground-water storage and soil-water storage, and annual evapotranspiration (*ET*) are shown in tables 5.8 and 5.9 for watersheds W–2 and W–3. Data for the two watersheds reveal different characteristics for the two areas. Before results are discussed, the periods for comparison should be brought to the readers' attention.

As stated in section 4, channelization and construction of water-level control structures that were part of the Public Law 566 project were completed in W–3 during 1964. However, further private channelization completed in 1966 extended the Taylor Creek channel and increased the drainage area of W–3 from 15.7 square miles to 19.1 square miles. Construction was completed in 1968 within W–2 outside watershed W–3, after the nonconstruction period 1965–67. Therefore, table 5.8 shows three periods for comparison with W–2: (1) 1959–63, before treatment; (2) 1964–68, construction and transition period; and (3) 1969–73, after-treatment period. For uniformity of comparisons, table 5.9 shows the same three periods for W–3.

Table 5.8 shows little difference in average annual precipitation and considerable difference in streamflow between the before-treatment and transition periods. The average annual *ET* was significantly greater during the transition period, corresponding to a smaller streamflow. A comparison of the before- and after-treatment periods shows that precipitation was only slightly different and streamflow was about the same, but *ET* was significantly greater after treatment. The difference in *ET* was greater than the difference in precipitation. *ET* values for the transition and after-treatment periods are in close agreement. As discussed in an earlier section, streamflow calculations made after channelization and construction of water-level control structures are not as accurate as those made before treatment as a result of operation of the Tainter gates, which may be a factor in the differences in *ET*. If the differences can be attributed to treatment, the construction of Tainter gate structure S–1 (initial construction) was the cause of the differences. This coincides with the previous statement on quality of records following construction. The data in table 5.8 also show that the long-term change in ground-water storage was significant

Table 5.8.—Annual precipitation, streamflow, ground-water storage, soil-water storage, and evapotranspiration, in inches, for watershed W–2[1]

Year	Precipi-tation	Stream-flow	Change in ground-water storage	Change in soil-water storage	*ET*
1959	61.39	25.68	−0.77	−0.41	34.53
1960	59.02	31.41	+1.64	+.61	29.86
1961	30.41	.59	+3.35	+.67	33.84
1962	51.28	17.75	−3.04	−.63	29.86
1963	38.29	1.75	−2.28	−.86	33.40
5-year average	48.08	15.44	−0.22	−0.13	32.30
1964	44.55	9.13	+1.22	+0.62	37.26
1965	37.91	2.39	+1.06	+.27	36.85
1966	55.49	15.17	+.29	+.05	40.66
1967	48.80	11.91	−.70	+.19	36.00
1968	51.90	19.66	−.25	−.01	31.98
5-year average	47.73	11.65	+0.32	+0.15	36.55
1969	65.00	29.14	−1.68	−0.76	33.42
1970	49.32	14.55	+4.01	+1.23	40.01
1971	48.85	13.31	−2.20	−.42	32.92
1972	41.83	5.59	+.65	+.13	37.02
1973	48.55	9.18	−.68	−.17	38.52
5-year average	50.71	14.35	+0.02	0.00	36.38
15-year average	48.84	13.81	+0.04	+0.01	35.08

[1]Increase in soil-water storage or ground-water storage is a negative value in the evapotranspiration (*ET*) calculation (eq. 5.21), thus the negative and positive values in the table.

in determination of *ET*, whereas the long-term change in soil-water storage contributed little to *ET* estimates. On a year-to-year basis, the changes in both storages are significant.

The data for subwatershed W–3 (table 5.9) reveal little difference in after-treatment periods. Operation of the single Tainter gate at structure S–3 was better documented, and thus the quality of streamflow data is better than that for watershed W–2. Neither ground-water-storage changes nor soil-water-storage changes were significant in estimating *ET* over the long term. As was the case for W–3, year-to-year changes are significant.

In view of the above discussions on the possible effects of quality of data, comparisons of watersheds must be considered very carefully. It is significant, however, that estimated *ET* before treatment was more than 2 inches greater for W–3 than for the total Upper Taylor Creek watershed (W–2). This is because W–3 is at a higher elevation on the landscape and the water table is normally nearer the ground surface than it is in the area below W–3. With a higher water table, *ET* possibly approaches potential *ET* for longer periods of time during the year. So the difference in *ET* before and after treatment on W–2 may be realistic. That is, construction of water-level control structures may have resulted in a relatively higher water table in the lower landscape portion of W–2. A higher water table could result in a higher *ET*. Ground-water duration analysis in section 4.3.2.1 showed little difference between treatment periods for wells 1 and 2, which were within W–3. Ground-water duration curves for wells 3 and 5 were significantly higher after treatment. These two wells were outside W–3. After treatment, estimated *ET* for W–2 was about the same as that for W–3. The 15-year average annual *ET* for W–3 is also about the same as that for W–2.

Estimated annual evapotranspiration for the watersheds is realistically based, and the order of magnitude is realistic. The often-used precipitation-minus-streamflow estimate of long-term average annual *ET* gives values of approximately 36 inches for both watersheds. It should be emphasized that these estimated values are for specific

Table 5.9.—Annual precipitation, streamflow, ground-water storage, soil-water storage, and evapotranspiration, in inches, for subwatershed W-3[1]

Year	Precipi-tation	Stream-flow	Change in ground-water storage	Change in soil-water storage	*ET*
1959	54.96	17.99	−0.57	−0.18	36.22
1960	62.05	26.52	+1.99	+.50	38.02
1961	30.62	.48	+2.68	+1.05	33.87
1962	50.07	14.68	−2.86	−1.12	31.41
1963	41.83	2.03	−2.45	−.72	36.63
5-year average	47.91	12.34	−0.24	−0.09	35.23
1964	46.23	10.59	+1.13	+0.43	37.20
1965	36.35	3.47	+1.78	+.47	35.13
1966	49.67	11.31	+.37	+.17	38.90
1967	44.38	10.66	−.73	−.30	32.69
1968	48.84	16.25	+.37	+.08	33.04
5-year average	45.09	10.46	+0.58	+0.17	35.39
1969	58.88	20.85	−1.39	−0.37	36.27
1970	46.26	10.24	+2.87	+1.01	39.90
1971	51.52	13.43	−1.47	−.67	35.95
1972	44.50	5.34	+.18	+.05	39.39
1973	49.01	13.70	−.18	−.13	35.00
5-year average	50.03	12.71	0.00	−0.02	37.30
15-year average	47.68	11.84	+0.11	+0.02	35.97

[1]Increase in soil-water storage or ground-water storage is a negative value in the evapotranspiration (*ET*) calculation (eq. 5.21), thus the negative and positive values in the table.

watersheds with specific land use. In 1955, Parker et al. (*35*) estimated the 16-year average annual water loss for the Kissimmee River basin as 42.54 inches. The method used in their investigation considered change in base flow for the year as an indication of change in storage. With only precipitation minus streamflow, the 16-year average was 42.41 inches. Precipitation in the Kissimmee basin was slightly greater than the 15-year averages shown in table 5.8 and 5.9, but streamflow was 5 to 7 inches less than that for the Upper Taylor Creek watersheds. This can be accounted for, at least partially, by the fact that the Kissimmee River heads in the central Florida highlands with many lakes, which can result in increased open-surface evaporation. Some of the lakes contribute significantly to recharge of the Floridan aquifer (*27*).

Average annual potential *ET* for the Taylor Creek area is given in the Water Atlas of the United States as about 47 inches (*14*). Actual *ET* would be considerably less than potential *ET* for much of the year, especially during the dry season of mid-October through mid-May.

5.4.2.—Monthly and Seasonal Data

Water within a watershed is in a continuous transient state at all times; i.e., channel flow, overland flow, ground-water flow, precipitation, and soil-water movement. The larger the watershed, the longer the time required to reach a near steady state. The most nearly steady state condition occurs during a prolonged dry period.

Since climate is cyclic on an annual basis, the assessment of water content in a watershed once a year at the same time will yield about the same conditions year after year with only minor differences. This was shown to be the case in the discussion of annual *ET* in section 5.4.1. However, when the sampling or assessment interval is decreased to less than annual, the transient nature becomes more dominant, and the degree of transilience is more apparent; i.e., monthly is more apparent than seasonal, and weekly is more apparent than monthly. Therefore, estimates of *ET* on a seasonal, monthly, and weekly basis become more erratic. If a storm occurs on

the last day of the month, most of the storm runoff will not occur until the following month. The ground water and soil water may not have accounted for the water content of the watershed, and *ET* for the first month will be high and for the second month will be low. In developing a 5-day water-yield model, Snyder, Mills, and Stephens (*44*) showed that only 40 percent of the effective rainfall that appeared as streamflow from Taylor Creek occurred during the 5-day period in which rainfall occurred, and 48.5 percent occurred in the following 5-day period. The remaining 11.5 percent was distributed over several succeeding 5-day periods. Such a carryover can certainly result in erratic *ET* estimates for monthly and shorter time intervals.

Monthly *ET* was determined for watersheds W–2 and W–3 for the 15-year period January 1959 through December 1973 with equation 5.21. As expected, the values were quite variable, and some adjustments were made where exceptionally high values were followed by exceptionally low values, or in some cases, where negative amounts were determined. After adjustments, averages were determined for each month. Monthly averages of *ET*, pan evaporation, radiation, and temperature are given in table 5.10. Monthly average *ET* for the two watersheds is also given, since there is little difference between amounts for the watersheds. Although it was shown in section 5.4.1 that annual *ET* for W–2 was greater after treatment than before treatment, all data for the 15-year period were averaged. The longer averaging period is needed for the monthly estimates because of the high degree of variability. Monthly averages of *ET*, pan evaporation, radiation, and temperature are shown in figure 5.49. Maximum monthly radiation and pan evaporation occurred in May, but maximum *ET* occurred in June on W–3. The *ET* values in June and July are about equal for W–2. Even though the individual monthly data are highly variable, the June high is real. This is caused by the lag of heat transfer from the atmosphere to the soil. Mean monthly air temperature peaked in August. The high June *ET* coincides with the beginning of the rainy season when more water was available, and actual *ET* probably approached potential *ET*.

Most evapotranspiration studies have been conducted in the irrigated areas of the western United States. Pruitt and Jensen (*36*) related consumptive use of water to pan evaporation. Studies by Gray, Levine, and Kennedy (*15*) indicated that growing-season *ET* for pasture crops in the arid areas is about equal to pan evaporation, but the authors gave a value of 75 percent of pan evaporation in humid areas. Harrold (*16*) reported that lysimeter data

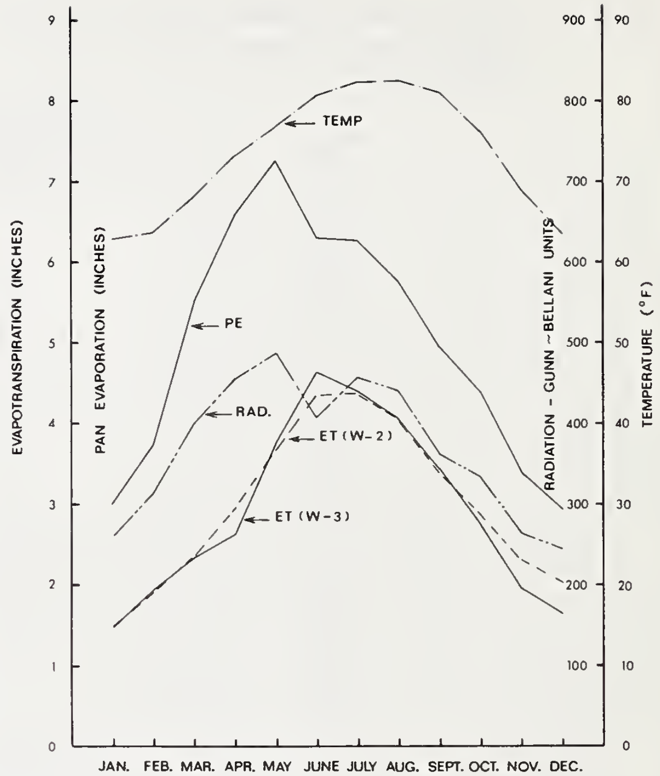

FIGURE 5.49.—Mean monthly evapotranspiration, pan evaporation, radiation, and temperature, watersheds W–2 and W–3, January 1959–December 1973. The values for pan evaporation, radiation, and temperature are monthly averages of W–2 and W–3. (ET, evapotranspiration; PE, pan evaporation; RAD., radiation; TEMP., temperature.)

from Coshocton, Ohio, showed *ET* percentages of pan evaporation were 1.0, 0.5, and 1.5 for May, June, and July-August, respectively. The low June value was attributable to the dry conditions that existed at Coshocton for the month.

Ratios of monthly average *ET* to monthly average pan evaporation are shown in table 5.10. The ratios range from 0.42 in April to 0.74 in June and August. The low April value was probably caused by the normally dry conditions that result from the dry season beginning in late September or October. The ratio increases from April to May, since the rainy season sometimes begins in late May. Likewise, the September value is the lowest of the rainy seasons, since the dry season may begin in late September or about mid-October in some years. Seasonal average ratios are given in table 5.10 for the periods as

Table 5.10.—Mean monthly and annual evapotranspiration, pan evaporation, and radiation; mean monthly temperature; and ratio of monthly average evapotranspiration to monthly average pan evaporation for January 1959–December 1973[1]

Month	Evapotranspiration (inches) W–2	W–3	Avg.	Pan evaporation (inches)	Radiation Gunn-Bellani units	Temperature (°F)	Ratio $ET : PE$[2]	Average ratio
January	1.45	1.48	1.46	3.00	261	62.9	0.49	
February	1.91	1.92	1.92	3.73	315	63.7	.51	
March	2.35	2.51	2.43	5.49	399	68.0	.44	0.47
April	2.81	2.60	2.70	6.58	456	72.9	.41	
May	3.59	3.82	3.70	7.26	476	76.6	.51	
June	4.40	4.83	4.62	6.29	406	80.6	.73	
July	4.33	4.58	4.46	6.27	457	82.2	.71	.72
August	4.04	4.32	4.18	5.74	440	82.5	.73	
September	3.26	3.51	3.38	4.93	360	81.1	.69	
October	2.71	2.74	2.72	4.40	334	76.3	.62	
November	2.26	2.01	2.14	3.39	262	69.0	.63	.62
December	1.97	1.65	1.81	2.93	243	63.7	.62	
Total	35.08	35.97	35.52	60.01	4,409	......	......	......
Average						73.3	0.59	......

[1]The values for pan evaporation, radiation, and temperature are monthly averages of W–2 and W–3.

[2]*ET*, evapotranspiration. *PE*, pan evaporation.

follows: (1) late dry season, January through May; (2) rainy season, June through September; and (3) early dry season, October through December. Sufficient carryover water is available in the third period for relatively high *ET* rates. The rainy-season ratio of 0.72 compares favorably with that estimated by Gray, Levine, and Kennedy (*15*). On an annual basis, the ratio *ET* to pan evaporation is about 0.60. The 15-year average pan evaporation of 60.01 inches for Upper Taylor Creek watershed is slightly less than the 64 inches interpolated from the USWB map for the 10-year period 1946–55 (*28*).

Evapotranspiration was much lower during November and December for W–3 than for W–2 (table 5.10 and figure 5.49). The *ET/PE* ratio was 0.58 for W–3 and 0.68 for W–2 over the span of those 2 months. The vegetation in W–3 was largely improved subtropical pasture grasses. These grasses become senescent and dormant late in the year, and hence decrease transpiration sharply. Also, *ET* was much less for W–3 than W–2 during April. The improved subtropical pasture grasses are usually heavily grazed with low amounts of leaf area during this month of high solar radiation loads and low rainfall. Vegetation on the whole watershed W–2 varied from swamps and wetlands, forests, unimproved pasture, as well as improved pasture.

During most of the remainder of the year, *ET* on W–3 equaled or exceeded *ET* on W–2, especially during the summer months when the improved pastures were most vigorous.

Another contributing factor to difference in *ET* is that W–3 lies mostly at higher elevations that may dewater more during November and December than the watershed as a whole.

Although *ET* data for individual months are highly variable, the average monthly values appear realistic. Ratios of *ET* to pan evaporation for the rainy season are in agreement with ratios found at other locations. These ratios can be used, by month or season, for use in water-resources planning and management of the region.

ET estimates for 14-day intervals were made for both watersheds; however, these data were so highly variable that little benefit could be seen. The carryover effect from interval to interval was of such magnitude for these large watersheds that 14-day *ET* was not considered worthwhile.

5.5.—Water Quality

Water-quality research was not a part of the original plan in the Upper Taylor Creek watershed studies, and it was not until 1972 that water chemistry was added to the study. Observations of water quality were not made before channelization, so treatment effects could not be determined. However, the survey-type information is of sufficient interest to be included here.

A nutrient budget study for Lake Okeechobee was made by the USGS in 1969–70 (*24*). This study showed that streamflow from Taylor Creek and Nubbin Slough watersheds contributed 7 percent of the total stream-water inflow into the lake and contributed 36 percent of the streamflow phosphorus and 10 percent of the streamflow nitrogen into the lake. The alarming phosphorus load prompted the design of a water-quality survey in Upper Taylor Creek watershed to determine the subunits of the watershed from which the plant nutrients were originating. A second study by the Central and Southern Florida Flood Control District in 1973–74 reported that the Taylor Creek/Nubbin Slough drainage contributed 11 percent of the stream inflow, 43 percent of the streamflow phosphorus, and 9 percent of the streamflow nitrogen, which confirmed the heavy phosphorus loads (*1, 10*).

Open-channel sites and ground-water observation wells were selected within the watershed for periodic sampling. Sample collection began on March 23, 1972, at four sampling sites, which included water from a Floridan aquifer artesian well in watershed W–5. These samples were analyzed by the University of Georgia Soils and Plant Testing Laboratory, Athens (table 5.11), and the Surveillance and Analysis Division, Chemical Services Branch, U.S. Environmental Protection Agency, Athens, Ga. (table 5.12). The survey was implemented at 11 sites on April 19, 1972, and samples were collected at 2-week intervals through July 1972 and then at monthly intervals until January 3, 1973. Pint samples of streamflow were obtained with a USGS DH–48, depth integrating, hand sampler on a wading rod. The sampler traversed the depth at only one point in the stream cross section. The samples were processed in the Aquatic Weed Laboratory at the University of Florida Agricultural Research Center, Fort Lauderdale. Personnel changes resulted in termination of the survey until March 19, 1974; data are reported here for the survey through December 30, 1975. Generally, samples were collected at 1- or 2-week intervals in 1974 and 1975 and were analyzed at the University of Florida Agricultural Research Center, Fort Pierce. All samples were analyzed in accordance with standard methods (*2*). The 1972 survey data were reported by Allen et al. (*1*) in 1975, and the 1974–75 survey information was summarized by Stewart et al. (*49*). This work contains plant nutrient and chloride data for 1972 and 1974–75 for Upper Taylor Creek watershed and three subwatersheds only. The two previous analyses are not duplicated in this paper; however, chemical analyses of all samples taken in 1972, 1974, and 1975 are shown in tables A–28 through A–32.

Only the 1972 water-quality data have been analyzed in detail in this report. The 1974 and 1975 water-quality data in tables A–29 through A–32 substantiate the findings and conclusions of the following sections, 5.5.1 and 5.5.2.

Table 5.11.—Concentrations of selected elements in samples collected from streams near Taylor Creek runoff gaging stations for comparison with samples from an artesian well in the Floridan aquifer[1]

Element	W–2A[2] (mg/l)	Site 3, W–3 (mg/l)	Site 5, W–5 (mg/l)	Artesian well[3] (mg/l)
P	<1.0	<1.0	<1.0	<1.0
K	<6.0	7.0	12.5	21.0
Ca	50.0	38.0	150.0	180.0
Mg	16.0	15.5	72.0	190.5
Mn	<.001	<.001	<.001	<.001
Fe	.113	.172	.296	.114
B	.062	.066	.116	.156
Cu	.008	.008	.096	.033
Zn	<.011	<.011	.050	([4])
Al	.113	.103	.266	.348
Sr	2.00	2.40	17.60	32.40
Ba	.011	.008	([4])	([4])
Na	60.4	64.8	717.2	1,000.4

[1]Samples analyzed by University of Georgia Soils and Plant Testing Laboratory, Athens.
[2]Represents entire W–2 area less W–5.
[3]In W–5, near rain-gage 7.
[4]No record.

5.5.1.—Streamflow

Streamflow analyses are treated in earlier sections of this work, but since water quantity is an integral part of water quality, this section treats the streamflow data separately for the years 1972, 1974, and 1975. Also, the stream

Table 5.12.—Water-quality analyses of samples collected from three open channels in Taylor Creek watershed for comparison with samples from an artesian well in the Floridan aquifer[1]

Station	Conductivity (μmho/cm)	Chloride (mg/l)	TOC (mg/l)	TKN (mg/l)	NH_3-N (mg/l)	NO_3+NO_2-N (mg/l)	Total P (mg/l)	Orthophosphate (mg/l as P)	Turbidity (JTU)
Site 2 (W-2A)[2]	610	90	12	0.37	0.10	0.01	0.24	0.17	2
Site 3 (W-3)	570	85	12	.45	.04	<.005	.26	.24	2
Site 5 (W-5)	3,000	950	10	.57	.20	.35	.40	.46	4
Artesian well[3]	4,200	1,840	3	.40	.25	.01	<.01	<.01	<1

[1]TOC = Total organic carbon. TKN = Total Kjeldahl nitrogen. JTU = Jackson turbidity units. Samples analyzed by Surveillance and Analysis Division, Chemical Services Branch, U.S. Environmental Protection Agency, Athens, Ga.

[2]Represents entire W-2 area less W-5.

[3]In W-5, near rain-gage 7.

regimen was changed in the lower reaches in 1973, and the 1974–75 streamflow data are not analyzed in the earlier sections.

The following four areas (fig. 5.50) were selected for analysis to provide comparisons of land use and treatment: watershed W-2, subwatersheds W-3 and W-5, and an additional subwatershed, W-13 (Otter Creek). The surface drainage area for W-13 is 11.1 square miles. Although streamflow from this subunit flows through a water-level control structure (S-13), streamflow was not measured. Estimates of streamflow for W-13 were made for the water quality study period by use of streamflow data from W-2 and W-3 with correction for differences in rainfall between the two areas. These estimates are not exact, but they are in the right order of magnitude and are adequate to draw inferences on water quality.

Land-use data for W-2 and W-3 are given in section 1.2.5. For comparative purposes, W-3 primarily consists of improved beef-cattle pasture; W-13 consists mainly of intensive dairy operations including improved dairy pasture; and W-5 includes improved beef-cattle pasture, unimproved pasture, and citrus groves with irrigation from artesian wells. That portion of watershed W-2 outside W-3, W-5, and W-13 includes unimproved pasture and improved beef-cattle and dairy pasture.

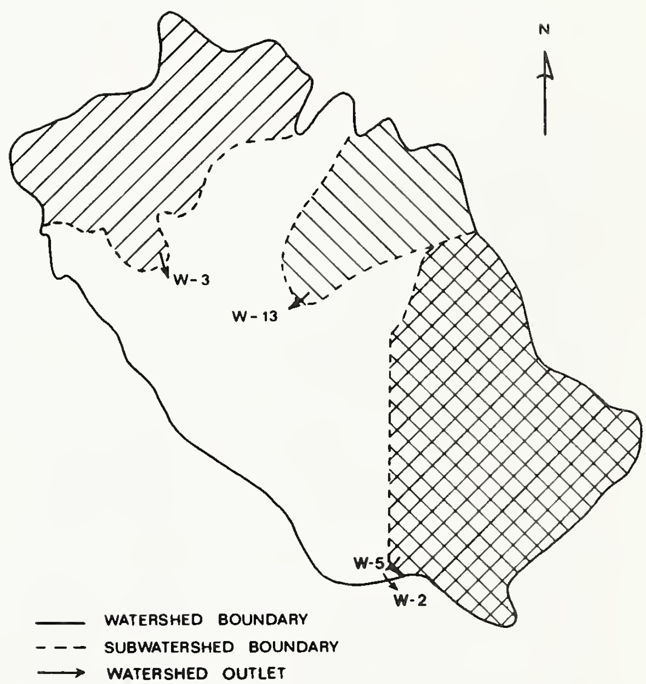

FIGURE 5.50.—Boundary map of watershed W-2 and subwatersheds used in water-quality study. (Watershed boundaries before January 1967.)

In 1973, the lower reach of Taylor Creek was changed by the South Florida Water Management District (SFWMD), formerly the Central and Southern Florida Flood Control District. A structure (S-192) was built across the mainstream channel below the W-2 gaging station at Cemetery Road. Taylor Creek streamflow was diverted into an interceptor canal (L-63N) that also picks up discharge from Nubbin Slough, Lettuce Creek, and Mosquito Creek and from some lesser sources of local drainage. Flow from the interceptor canal discharges into Lake Okeechobee through structure S-191. The structure is normally closed but automatically opens when the water level in the canal

Table 5.13.—Quarterly and annual rainfall and streamflow, in inches, for watersheds W-3, W-13, W-5, and W-2

Year	Quarter	W-3 Rainfall	W-3 Streamflow	W-13 Rainfall	W-13 Streamflow	W-5 Rainfall	W-5 Streamflow	W-2 Rainfall	W-2 Streamflow
1972	1	6.02	0.43	6.04	0.51	7.78	0.55	6.87	0.46
	2	14.40	1.00	13.91	1.27	11.77	1.59	13.21	1.56
	3	17.86	3.47	18.40	3.66	13.52	1.71	15.16	3.07
	4	6.22	.44	5.36	.48	6.90	.38	6.59	.50
	Total	44.50	5.34	43.71	5.92	39.97	4.23	41.83	5.59
1974	1	2.82	0.22	2.01	0.16	1.66	0.26	2.14	0.17
	2	17.05	1.10	15.73	1.67	16.48	.87	17.00	.96
	3	23.15	14.71	27.16	15.43	22.68	11.36	23.52	12.20
	4	3.87	1.37	4.62	.97	4.31	1.00	4.16	.95
	Total	46.89	17.40	49.52	18.23	45.13	13.49	46.82	14.28
1975	1	3.30	0.08	2.44	0.14	3.38	0.30	3.25	0.16
	2	12.13	.20	11.69	.24	15.02	.44	13.20	.19
	3	19.00	2.25	15.62	2.02	17.27	2.64	17.86	2.06
	4	6.09	2.27	3.21	.72	3.33	.90	4.24	.92
	Total	40.52	4.80	32.96	3.12	39.00	4.28	38.55	3.33

reaches a specified level, permitting gravity flow into the lake. Closing of the gate is also actuated by water level. Flow from the canal is intermittent, and, during prolonged dry periods, several days may lapse without flow. Canal storage from all the sources results in backwater into Taylor Creek well above the W-2 gaging station. The USGS installed a calibrated deflection vane at Cemetery Road bridge to measure the velocity of the stream at that point. Observation of deflection-vane charts revealed that when the gate at structure S-191 was closed, alternate negative and positive deflections were recorded for some finite time. This indicates surging in the relatively large canal. If a storm is centered over Nubbin Slough, Mosquito Creek, or Lettuce Creek watersheds and there is little or no rainfall in Taylor Creek watershed, a false impression of Taylor Creek discharge can occur as a result of canal storage in and subsequent indicated outflow from Taylor Creek. Conversely, storms centered over Taylor Creek watershed can result in a low indicated discharge because of ponding into the large canal. For these reasons, "observed" streamflow for W-2 may well not have been the actual discharge from the watershed, thus the termination in 1972 of earlier hydrologic analyses. Also, the storage-surge conditions in the interceptor canal may have resulted in continued mixing and dilution of chemicals, and thus the "observed" concentrations and loads of chemicals may not have been accurate. They are considered in the right order of magnitude as given here. However, the user is cautioned about the existing flow conditions.

In the interest of space, the mass of streamflow and water-quality data cannot be presented in detail. Summaries of information for some finite time interval provide insight into the water-quality characteristics. A calendar quarter was considered to be a suitable time interval for presentation, so the streamflow data are presented on a quarterly basis, as are the chemical data in later sections. Streamflow data were unitized for subwatersheds W-3, W-5, and W-13 and for watershed W-2, for comparative purposes. The unitized data, in cubic feet per second per square mile, are shown in figure 5.51 for each calendar quarter of 1972, 1974, and 1975. Unit discharges for the watersheds compare relatively well for all quarters except the third for 1972 and 1974. The July-September quarter is within the normal rainy season, and under the convective-thunderstorm rainfall of the region, the differences between watersheds can be expected.

Quarterly and annual rainfall and streamflow volumes are given in table 5.13 for each subwatershed and watershed W-2. Annual rainfall in 1974 was about equal to the long-term normal, and streamflow was about normal. In 1972, annual rainfall was only slightly below normal, but the distribution was such that streamflow was considerably below average. In 1975, annual rainfall and streamflow were well below the average. High rainfall and streamflow in the third quarter of 1974 produced hydrologic conditions that could have resulted in extreme

water-quality conditions. On an annual basis, streamflow from W-3 was greater than that from the total area (W-2). Streamflow from W-13 was greater in 1972 and 1974 but less in 1975 than that from the total area. Conversely, streamflow from W-5 was greater than that from the total area only in 1975. Table 5.14 shows the percentage of total land area and the percentage of annual discharge for subwatersheds W-3, W-5, and W-13.

Table 5.14.—Percentage of total watershed area for and of total annual discharge from subwatersheds W-3, W-13, and W-5

Watershed	Total area	Annual discharge 1972	1974	1975
W-3	18.3	17.5	22.3	26.3
W-13	10.6	11.2	13.6	10.0
W-5	33.9	25.6	32.0	43.5
W-2	100.0	100.0	100.0	100.0

5.5.2.—Plant Nutrients

The plant nutrients considered here are limited to nitrogen and phosphorus.

5.5.2.1.—Nitrate Nitrogen

Available resources of ARS in Florida limited the water-quality study to periodic sampling, with determination of pollutants readily measurable by existing equipment and personnel. The nitrogen cycle is complex, and measurement of nitrate nitrogen gives only part of the total picture. Measurements of nitrite nitrogen, ammonia nitrogen, and total nitrogen were not within the capabilities. However, these limitations did not seriously detract from the survey-type study nor from attaining the objectives, i.e., to determine the watershed subunits contributing heavily to streamflow quality degradation.

Nitrate-nitrogen loads were calculated for each watershed. The method of calculation was a simplified one in which the sample concentration on a date was assigned to all discharge occurring since the previous sampling date. That is, for example, if samples were taken on April 2 and April 16, the concentration for the 16th was applied to the total discharge from April 3 through 16. Other methods could have been used, but in view of the time interval between samples, little if any accuracy would have been gained.

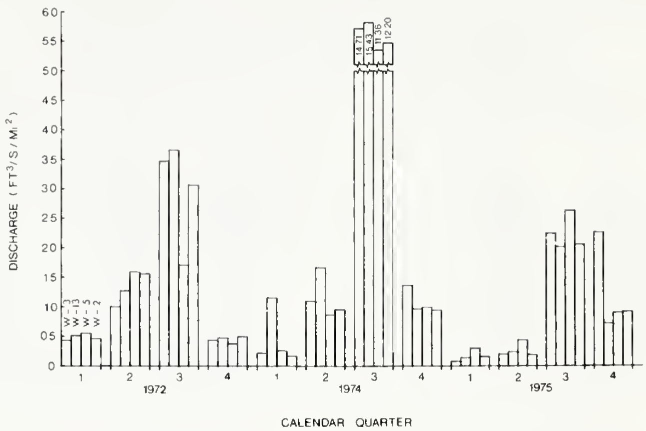

FIGURE 5.51.—Quarterly unit streamflow, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

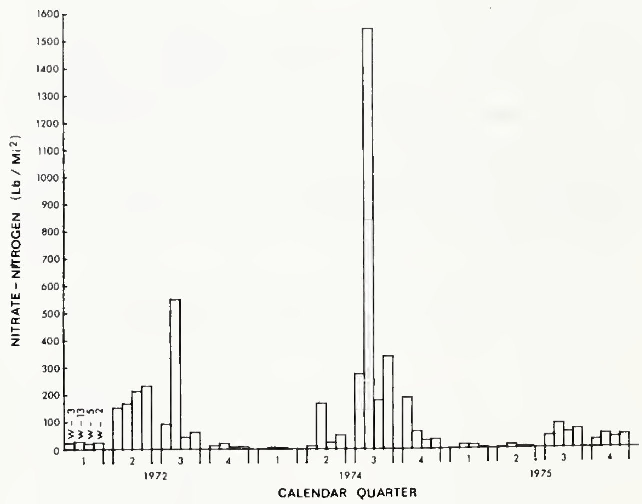

FIGURE 5.52.—Quarterly unit nitrate-nitrogen loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

Nitrate-nitrogen loads in pounds per square mile were determined for each calendar quarter of 1972, 1974, and 1975. As was the case with streamflow data, chemical-load data were unitized on a square-mile basis for ready comparison of the different sizes of watersheds. Unit-load nitrate-nitrogen data are shown in figure 5.52. Unit load was greatest from W-13 (intensive dairy unit) in all quarters except the second quarter of 1972 and the fourth quarter of 1974. The second highest nitrate-nitrogen unit load alternated between W-3 and W-5. Comparison of figure 5.51 with figure 5.52 shows that the pattern of nitrate-nitrogen load is similar to that of streamflow,

Table 5.15.—Percentages of total watershed area and annual nitrate-nitrogen loads, percentage each represents of total annual load, and ratios for subwatersheds W-3, W-13, and W-5[1]

Watershed	Total area	Nitrate-nitrogen loads for—								
		1972			1974			1975		
		Tons	Percent	Ratio	Tons	Percent	Ratio	Tons	Percent	Ratio
W-3	18.3	2.65	15.5	0.85	4.56	20.3	1.11	0.74	11.3	0.62
W-13	10.6	4.25	24.9	2.35	9.94	44.2	4.17	.94	14.3	1.35
W-5	33.9	5.02	29.5	.87	4.23	18.8	.55	2.04	31.1	.92
W-2	100.0	17.04	100.0	......	22.49	100.0	......	6.54	100.0	......

[1]Ratio is the percentage of nitrate nitrogen divided by the percentage of total watershed area.

which indicates a flushing-type condition as opposed to one of dilution by high flows. The peak quarterly load was 1,551 pounds per square mile for W-13 in the third quarter of 1974. The minimum load occurred from W-3 in the first quarter of 1975.

Quarterly weighted nitrate-nitrogen concentrations were determined from the load and discharge data. The quarterly concentrations are shown by watershed in figure 5.53. The relationship of concentration vs. load was not very clear, perhaps because nitrate nitrogen is a biologically active nutrient that can be readily converted to other nitrogen species.

Nitrate-nitrogen concentrations of individual samples ranged from a low of less than 0.04 mg/l to a maximum of 2.70 mg/l at W-13 on August 1, 1972. Maximum concentrations were well below the Public Health Service upper limit of 15 mg/l for drinking water (*9*). A summary of nitrate-nitrogen load contributions is given in table 5.15. Subwatershed contributions as percentages of the W-2 loads show that W-13 is always greater than the percentage of total land area.

In summary, the largest unit percentage of nitrate nitrogen in Taylor Creek streamflow originated in dairy-intensive subwatershed W-13 (Otter Creek). There is little difference between the unit contribution from beef-cattle pasture (W-3) and the combination of beef-cattle pasture and citrus groves (W-5). Annual loads of nitrate-nitrogen discharging from Taylor Creek into Lake Okeechobee ranged from 6.54 to 22.49 tons for the 3 years of record.

Nitrate-nitrogen constitutes only a part of the forms of nitrogen moving in Taylor Creek watershed. Davis and Marshall (*10*) found that nitrate nitrogen was about 8 percent of the nitrogen that flowed from Taylor Creek/Nubbin Slough to Lake Okeechobee.

Federico (*12*) compared components of nitrogen and phosphorus at W-3 and W-13 during four 4-day intensive sampling periods in July to September 1975. He found that total Kjeldahl nitrogen averaged 1.81 mg/l for W-3 and 6.52 mg/l for W-13, with 0.74 mg/l (4.0 percent) and 0.216 mg/l (3.3 percent), respectively, being nitrate nitrogen, and 0.05 mg/l (2.8 percent) and 3.53 mg/l (54.1 percent), respectively, being ammonia nitrogen. The weighted concentrations of nitrate-nitrogen during the third quarter were 0.14 mg/l for W-3 and 0.31 mg/l for W-13. These data indicate that nitrate-nitrogen makes up only a small component of the nitrogen outflows on Taylor Creek watershed and cannot be definitive for any nitrogen transport studies. Also, the ammonia-nitrogen form is of major significance in these dairy-intensive land use areas (W-13).

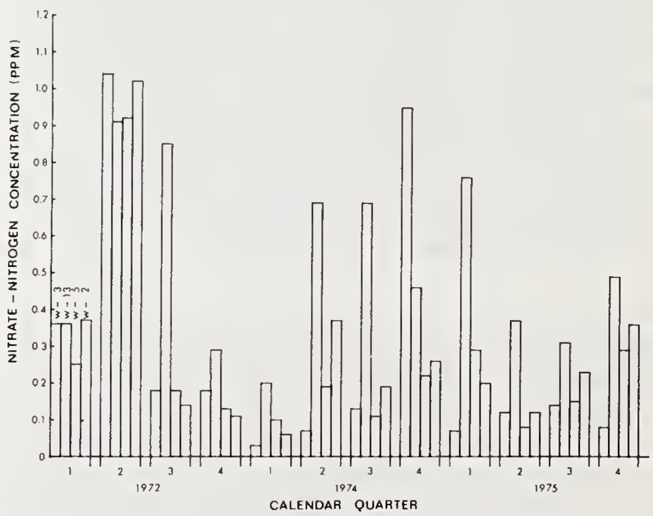

FIGURE 5.53.—Quarterly weighted nitrate-nitrogen concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

Table 5.16.—Percentages of total watershed area and annual orthophosphate-phosphorus loads, percentage each represents of total annual load, and ratios for subwatersheds W-3, W-13, and W-5[1]

Watershed	Total area	Orthophosphate-phosphorus loads for— 1972 Tons	1972 Percent	1972 Ratio	1974 Tons	1974 Percent	1974 Ratio	1975 Tons	1975 Percent	1975 Ratio
W-3	18.3	6.66	15.7	0.86	12.02	15.2	0.83	2.97	15.5	0.85
W-13	10.6	19.17	45.3	4.27	40.01	50.5	4.76	6.10	31.8	3.00
W-5	33.9	3.84	9.1	.27	16.38	20.7	.61	5.39	28.0	.83
W-2	100.0	42.32	100.0	......	79.27	100.0	......	19.22	100.0	......

[1]Ratio is the percentage of orthophosphate phosphorus divided by the percentage of total watershed area.

5.5.2.2.—Orthophosphate Phosphorus

Sediment transport in Taylor Creek and its tributaries is negligible because of the dominance of pasture, high infiltration rate of the sandy soils, water-level control structures, flat terrain, and low clay content of the soils. Therefore, transport of phosphorus adsorbed to soil particles is negligible, and only the water phase was considered in the water-quality survey. As in the case of nitrate nitrogen, only orthophosphate-phosphorus concentrations were determined, because of resource limitations. Data from the SFWMD (*10*) showed that about 78 percent of the phosphorus in Taylor Creek/Nubbin Slough flow into Lake Okeechobee was orthophosphate phosphorus.

Orthophosphate-phosphorus loads for each watershed were calculated for each calendar quarter in the same manner as those for nitrate-nitrogen. Quarterly unit loads are shown in figure 5.54. Unit load for W-13 was greatest in all quarters except the fourth quarter of 1974. The orthophosphate-phosphorus unit loads closely approximate the pattern for unit streamflow. The largest load, 6,631 pounds per square mile, occurred in the third quarter of 1974. This was more than double the second highest load of 2,937 pounds per square mile for W-13 in the third quarter of 1972. The second largest contributing subwatershed was W-3. Total annual loads, percentages, and ratios are summarized in table 5.16. Ratios of percentage of orthophosphate-phosphorus contribution to percentage of land area for W-13 ranged from 3.00 to 4.76. Other ratios were less than unity. The annual loads discharged by streamflow into Lake Okeechobee ranged from 19.22 to 79.27 tons for the 3 years of record.

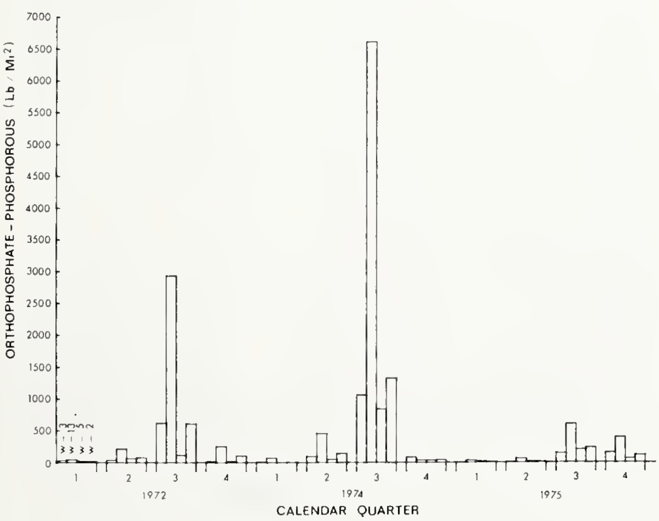

FIGURE 5.54.—Quarterly unit orthophosphate-phosphorus loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

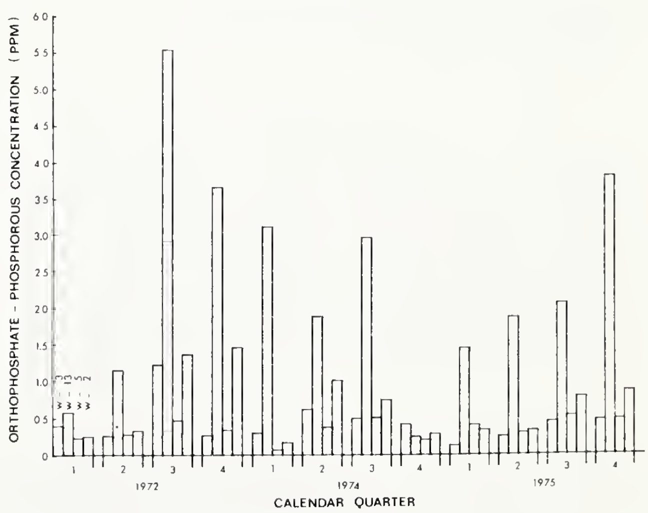

FIGURE 5.55.—Quarterly weighted orthophosphate-phosphorus concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

Quarterly weighted orthophosphate-phosphorus concentrations were determined for each watershed each quarter (fig. 5.55). Weighted concentrations for W-13 greatly exceeded those for other watersheds except in the fourth quarter of 1974 when the concentration for W-3 was the largest. Maximum weighted concentration was 5.54 mg/l at W-13 in the third quarter of 1972. Maximum sample concentration was 18.80 mg/l at W-13 on August 1, 1972. In 1952, Odum (*32*) found that dissolved phosphorus concentrations in streamflow were higher in areas where phosphate deposits occurred. At that time, less than 0.06 mg/l of dissolved phosphorus was found in the only sample reported from Taylor Creek.

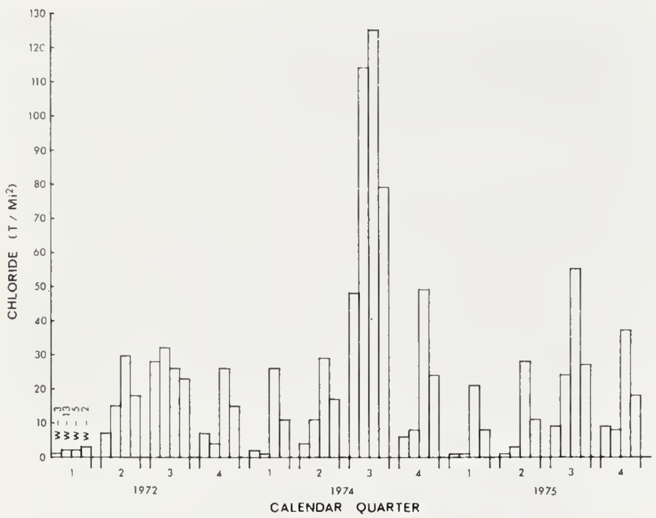

FIGURE 5.56.—Quarterly unit chloride loads, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

As was the case with nitrate nitrogen, the discharge of orthophosphate phosphorus seems to be a flushing action as opposed to dilution during high runoff periods. Attempts to relate loads and concentrations resulted in scatter diagrams without defined relationships. In summary, orthophosphate-phosphorus unit loads were largest from the dairy-intensive area, next in size from the beef-cattle pasture, and smallest from the combination of pasture and citrus.

During July to September 1975, Federico (*12*) found an average of 0.453 mg/l total phosphorus in W-3 and 2.97 mg/l total phosphorus in W-13 streamflow, with 0.297 mg/l (66 percent) and 2.16 mg/l (73 percent) as orthophosphate phosphorus. Our orthophosphate-phosphorus weighted concentrations during the third quarter of 1975 were 0.45 mg/l and 2.07 mg/l for W-3 and W-13. So, orthophosphate phosphorus appears to be a reliable indicator of total phosphorus concentration. Also, both total phosphorus and orthophosphate phosphorus are several-fold higher in concentration in intensive dairy land use areas than in beef production land use areas.

5.5.3.—Chloride

Chloride content of streamflow can often be related to heavy organic-fertilizer applications or to municipal and industrial waste disposal. Table 5.12 shows that the chloride concentration in the water from the artesian well was quite high.

Quarterly unit chloride loads are shown in figure 5.56 for the four watersheds. In general, the unit loads were higher at W-5, which reflects the citrus irrigation from the Floridan aquifer. Except for the first quarter of 1972, chloride loads from W-5 averaged more than 20 tons per square mile. Total annual loads, percentages, and ratios are given in table 5.17. The annual data show that about one-half to three-fourths of the total Taylor Creek chloride load originated in W-5. The maximum quarterly unit load was 125 tons per square mile from W-5 in the third quarter of 1974.

Quarterly weighted chlorine-concentration values are shown in figure 5.57. Weighted concentrations for W-5

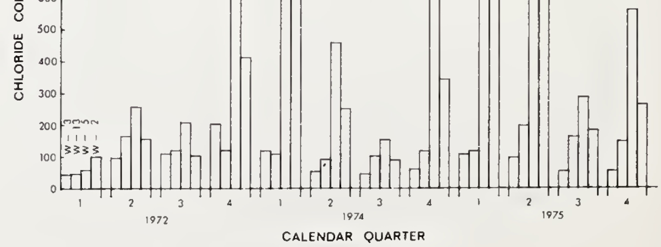

FIGURE 5.57.—Quarterly weighted chloride concentrations, watersheds W-2, W-3, W-5, and W-13 for 1972, 1974, and 1975.

Table 5.17.—Percentages of total watershed area and annual chloride loads, percentage each represents of total annual load, and ratios for subwatersheds W-3, W-13, and W-5[1]

Watershed	Total area	Chloride loads for— 1972 Tons	1972 Percent	1972 Ratio	1974 Tons	1974 Percent	1974 Ratio	1975 Tons	1975 Percent	1975 Ratio
W-3	18.3	813	13.2	0.73	1,157	8.4	0.46	376	5.6	0.31
W-13	10.6	586	9.5	.90	1,492	10.9	1.03	400	6.0	.57
W-5	33.9	2,983	48.3	1.42	8,147	59.3	1.57	4,985	74.8	2.21
W-2	100.0	6,177	100.0	1.00	13,740	100.0	1.00	6,662	100.0	1.00

[1]Ratio is the percentage of chloride divided by the percentage of total watershed area.

ranged from 208 to 1,385 mg/l for all quarters except the first quarter of 1972 and the third quarter of 1974. A maximum sample concentration of 2,105 mg/l was observed at W-5 on May 28, 1974. The chloride data of figure 5.57 indicate a dilution effect. The highest streamflow period was the third quarter of 1974, and weighted concentrations were not as high as for the drier periods of record. During wet periods, citrus groves are not irrigated, and leaching of chloride by rainfall occurs during these periods. Most of the time, concentrations in W-5 and W-2 far exceed the upper limit of 250 mg/l for drinking-water standards (*9*). Chloride concentrations and loads were greatest from W-5 with its significant artesian-well irrigation. Subwatersheds W-3 and W-13 were similar in chloride contribution, which indicates no significant difference between beef- and dairy-cattle pastures.

Literature Cited

(1) Allen, L. H.; Stewart, E. H.; Knisel, W. G.; and Slack, R. A. 1976. Seasonal variation in runoff and water quality from the Taylor Creek watershed, Okeechobee County, Florida. Proc. Soil Crop Sci. Soc. Fla. 35: 126–138.

(2) American Public Health Association. 1971. Standard methods for the examination of water and waste water. 13th ed., 874 pp. The Association, Washington, D.C.

(3) Bearden, H. W. 1972. Water available in canals and shallow sediments in St. Lucie County, Florida. Fla. Bur. Geol., Rep. Invest. 62, 50 pp.

(4) Burford, J. B. 1971. Hydrologic data for experimental agricultural watersheds in the United States, 1964. U.S. Dep. Agric. Misc. Publ. 1194, 460 pp.

(5) ______. 1972. Hydrologic data for experimental agricultural watersheds in the United States, 1966. U.S. Dep. Agric. Misc. Publ. 1226, 399 pp.

(6) ______. 1972. Hydrologic data for experimental agricultural watersheds in the United States, 1965. U.S. Dep. Agric. Misc. Publ. 1216, 568 pp.

(7) ______, and Clark, J. M. 1973. Hydrologic data for experimental agricultural watersheds in the United States, 1967. U.S. Dep. Agric. Misc. Publ. 1262, 634 pp.

(8) Butson, K. D., and Prine, G. M. 1968. Weekly rainfall frequencies in Florida. Univ. Fla. Agric. Exp. Stn. Circ. S-187, 41 pp.

(9) Camp, T. R. 1963. Water and its impurities. 355 pp. Reinhold, New York.

(10) Davis, F. E., and Marshall, M. L. 1975. Chemical and biological investigations of Lake Okeechobee, January 1973–June 1974. Interim report. Central and Southern Florida Flood Control District (West Palm Beach, Fla.) Tech. Publ. 75-1, 91 pp.

(11) DeCoursey, D. G., and Snyder, W. M. 1969. Computer-oriented method of optimizing hydrologic model parameters. J. Hydrol. 9: 34–56.

(12) Federico, A. 1977. Investigations of the relationship between land use, rainfall, and runoff quality in the Taylor Creek Watershed. South Florida Water Management District (West Palm Beach, Fla.) Tech. Publ. 77-3, 44 pp.

(13) Finneman, N. M. 1938. Physiography of Eastern United States. 714 pp. McGraw-Hill, New York.

(14) Geraghty, J. J.; Miller, D. W.; van Der Leeden, F.; and Troise, F. L. 1973. Water atlas of the United States. 122 pls. Water Information Center, Port Washington, N.Y.

(15) Gray, H. E.; Levine, G.; and Kennedy, W. K. 1955. Use of water by pasture crops. Agric. Eng. 36: 529–531.

(16) Harrold, L. L. 1955. Evapotranspiration rates for various crops. Agric. Eng. 36: 669–672.

(17) ______; Brakensiek, D. L.; McGuinness, J. L.; Amerman, C. R.; and Dreibelbis, F. R. 1962. Influence of land use and treatment on the hydrology of small watersheds at Coshocton, Ohio, 1938–1957. U.S. Dep. Agric. Tech. Bull. 1256, 194 pp.

(18) Hazen, A. 1930. Flood flows. 199 pp. John Wiley and Sons, New York.

(19) Hershfield, D. M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Weather Bur. Tech. Pap. 40, 115 pp.

(20) Hobbs, H. W. 1963. Hydrologic data for experimental agricultural watersheds in the United States, 1956–1959. U.S. Dep. Agric. Misc. Publ. 945, 447 pp.

(21) ______, and Burford, J. B. 1970. Hydrologic data for experimental agricultural watersheds in the United States, 1963. U.S. Dep. Agric. Misc. Publ. 1164, 465 pp.

(22) ______, and Crammatte, F. B. 1965. Hydrologic data for experimental agricultural watersheds in the United States, 1960–61. U.S. Dep. Agric. Misc. Publ. 994, 496 pp.

(23) Horton, R. E. 1945. Erosional development of streams and their basins—hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull. 56: 275–370.

(24) Joyner, B. F. 1971. Appraisal of chemical and biological conditions of Lake Okeechobee, Florida, 1969–70. U.S. Geol. Surv. Open-File Rep. 71006, 90 pp.

(25) Knisel, W. G. 1972. Response of Karst aquifers to recharge. Colo. State Univ. (Fort Collins) Hydrol. Pap. 60, 48 pp.

(26) ______, and Snyder, W. M. 1975. Stochastic time distribution of storm rainfall. Nord. Hydrol. 6: 242–262.

(27) Knochennus, D. D., and Hughes, G. H. 1976. Hydrology of Lake County, Florida. U.S. Geol. Surv. Water Resour. Invest. Rep. 76–72, 100 pp.

(28) Kohler, M. A.; Nordenson, T. J.; and Baker, D. R. 1959. Evaporation maps for the United States. U.S. Weather Bur. Tech. Pap. 37, 18 pp. and pls.

(29) Langbein, W. B., and others. 1947. Topographic characteristics of drainage basins. U.S. Geol. Surv. Water Supply Pap. 968–C., pp. 125–157.

(30) McCollum, S. H., and Pendleton, R. F. 1971. Soil survey of Okeechobee County, Florida. 134 pp. U.S. Soil Conservation Service, Washington, D.C.

(31) Mayer, P. G., and Olmstead, B. R. 1968. Hydraulic investigations of Tainter gates as flow measuring devices. Ga. Inst. Technol. Water Resour. Center Rep. WRC–0158.

(32) Odum, H. T. 1953. Dissolved phosphorus in Florida waters. Fla. Geol. Surv. Rep. Invest. 9, Part I., 40 pp.

(33) Palmer, W. C. 1965. Meteorological drought, U.S. Dep. Commer. Water Bur. Pic. Pap. 45, 58 pp.

(34) Parker, G. G., and Hoy, N. D. 1943. Geology and ground water of the Kissimmee River-Lake Okeechobee area, Florida. Proc. Soil Sci. Soc. Fla. 6: 20–70.

(35) ______; Ferguson, G. E.; Love, S. K.; and others. 1955. Water resources of southeastern Florida. U.S. Geol. Surv. Water-Supply Pap. 1255, 965 pp.

(36) Pruitt, W. D., and Jensen, M. E. 1955. Determining when to irrigate. Agric. Eng. 36: 389–393.

(37) Riebsame, W. E.; Woodley, W. L.; and Davis, F. E. 1974. Radar inference of Lake Okeechobee rainfall for use in environmental studies. Weatherwise 27(5): 206–211.

(38) Snedecor, G. W. 1953. Statistical methods. 4th ed., 457 pp. Iowa State College Press, Ames.

(39) Snyder, W. M. 1975. Continuous seasonal probability of extreme rainfall events. Hydrol. Sci. Bull. 20(2): 275–283.

(40) ______. 1975. Developing a parametric hydrologic model useful for sediment yield. *In* Present and Prospective Technology for Predicting Sediment Yields and Sources, pp. 220–230. U.S. Agric. Res. Serv. [Rep.] ARS–S–40. (Out of print.)

(41) ______. 1976. Time series data analysis and synthesis for research watersheds. U.S. Agric. Res. Serv. [Rep.] ARS–S–112, 33 pp.

(42) ______. 1976. Interpolation and smoothing of experimental data with sliding polynomials. U.S. Agric. Res. Serv. [Rep.] ARS–S–83, 34 pp.

(43) ______, and Asmussen, L. E. 1972. Subsurface hydrograph analysis by convolution. ASCE J. Irrig. Drainage Div. 98 (IR3): 405–418.

(44) ______; Mills, W. C.; and Stephens, J. C. 1971. A three-component nonlinear water-yield model. *In* Systems Approach to Hydrology, Ch. 19, pp. 19.1–19.16. Proc. Bi-Lateral U.S.-Japan Symp. Hydrol., 1st.

(45) ______, and Wallace, J. R. 1974. Fitting a three-parameter log-normal distribution by least squares. Nord. Hydrol. 5(3): 129–145.

(46) Speir, W. H.; Mills, W. C.; and Stephens, J. C. 1969. Hydrology of three experimental watersheds in southern Florida, a progress report. U.S. Agric. Res. Serv. [Rep.] ARS 41-152, 50 pp.

(47) Stephens, J. C., and Mills, W. C. 1965. Using the Cypress Creek formula to estimate runoff rates in the southern Coastal Plain and adjacent Flatwoods land resource areas. U.S. Agric. Res. Serv. [Rep.] ARS-41-95, 17 pp.

(48) ______, and Stewart, E. H. 1963. A comparison of procedures for computing evaporation and evapotranspiration. Int. Assoc. Sci. Hydrol. Publ. 62, pp. 123-133.

(49) Stewart, E. H.; Allen, L. H., Jr.; and Calvert, D. V. 1978. Water quality of streams on the Upper Taylor Creek watershed, Okeechobee County, Florida. Proc. Soil Crop Sci. Soc. Fla. 37: 117-120.

(50) Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union 38(6): 913-920.

(51) University of Florida Institute of Food and Agricultural Sciences. 1976. Water requirements of citrus. U.S. Water Resour. Counc. (Citrus Subcommittee) Rep. WRC-4, 3 pp.

(52) U.S. Agricultural Research Service, Soil and Water Conservation Research Branch. 1957. Monthly precipitation and runoff for small agricultural watersheds in the United States, 691 pp.

(53) U.S. Agricultural Research Service, Soil and Water Conservation Research Division. 1958. Annual maximum flows from small agricultural watersheds in the United States, 330 pp.

(54) U.S. Agricultural Research Service, Soil and Water Conservation Research Division. 1960. Selected runoff events for small agricultural watersheds in the United States, 374 pp.

(55) U.S. Agricultural Research Service, Southeast Watershed Laboratory Staff. 1977. The hydrology and hydrogeology of Ahoskie Creek watershed, North Carolina: data and analysis. U.S. Dep. Agric. Tech. Bull. 1563, 163 pp.

(56) U.S. Department of Agriculture. 1955. Water. U.S. Dep. Agric. Yearb. Agric. 1955, 751 pp.

(57) U.S. Geological Survey. Surface water supply of the United States. Pt. 2B. South Atlantic slope and eastern Gulf of Mexico basins, basins from Ogeechee River to Carrabelle River. Water-Supply Pap. 1956-60.

(58) U.S. Geological Survey. Water resources data for Florida. Vol. 1, pt. 1. Streams. Surface Water Rec. 1961-65.

(59) U.S. Geological Survey. Water resources data for Florida. Vol. 2, pt. 1. Streams—Southern Florida, Lake Okeechobee and the Everglades. Surface Water Rec. 1966-73.

(60) U.S. Soil Conservation Service. 1964. National Engineering Handbook, Sec. 4, Hydrology. The Service, Washington, D.C.

(61) U.S. Water Resources Council. 1976. Guidelines for determining flood flow frequency. U.S. Water Resour. Counc. Bull. 17, 196 pp.

(62) U.S. Weather Bureau. Climatological data for Florida, 1919-71. The Bureau, Washington, D.C.

(63) Yates, P., and Snyder, W. M. 1975. Predicting recessions through convolution. Water Resour. Res. 11(3): 418-422.

Appendix.—Data Summary

Table A-1.—Soil descriptions, erosion classes, and land capability classes, watershed W-2[1]

		Topsoil			Subsoil		Substratum		
Soil	Percent of area	Average depth (inches)	Structure	Permeability	Structure	Permeability	Average depth to (inches)	Permeability	Internal drainage
Myakka-Immokalee fine sand.	65	4	Structureless, fine, single grain.	Rapid	Structureless (hardpan).	Moderate	36	Rapid	Medium.
Basinger fine sand	8	4	do	do	Structureless	Rapid	40	Slow	Slow.
Felda-Manatee loamy fine sand.	6	8	Weak, fine, granular	Moderate	Weak, fine, granular (massive).	Slow	30	do	Do.
Wabasso-Bradenton fine sand.	4	4	Structureless, fine, single grain.	Rapid	Weak, fine, subangular, blocky.	Moderate	36-84	do	Medium.
Pompano-Charlotte fine sand.	3	2	do	do	Structureless, fine, single grain.	Rapid	48	do	Slow.
Placid fine sand	3	8	do	do	do	do	45	do	Do.
Felda, Pompano, Placid, Pamlico, ponded.	3	3	do	do	do	do	40	do	Do.
Pomello fine sand	2	4	do	Very rapid	do	Very rapid	60	Very rapid	Very rapid.
Okeelanto peat	2	12	Fibrous	Rapid	Structureless	Rapid	48	Slow	Slow.
Adamsville fine sand	2	4	Structureless, fine, single grain.	do	Structureless, fine, single grain.	do	48	Moderate	Medium.
Delray fine sand	1	12	do	do	do	do	48	Slow	Slow.
Parkwood fine sand	1	4	do	do	do	do	30	do	Do.

[1]Soils: (Revision) Predominantly fine sand surface which is very friable and has above average infiltration rates and little surface runoff until it becomes saturated. Generally underlain at about 3 ft by an organic hardpan of variable thickness and hardness. Slopes: 100 pct in 0-2 pct class. Erosion: Class 1-100 pct (Little or no erosion; small areas of plus deposition). Land Capability: Class and percent of area—I, zero pct; II, 1 pct; III, 3 pct; IV, 96 pct.

Source: Soil Survey of Okeechobee County, Florida (30). Percentages based on Okeechobee County averages.

Table A-2.—Soil descriptions, erosion classes, and land capability classes, subwatershed W-3[1]

		Topsoil			Subsoil		Substratum		
Soil	Percent of area	Average depth (inches)	Structure	Permeability	Structure	Permeability	Average depth to (inches)	Permeability	Internal drainage
Myakka-Immokalee fine sand.	77	4	Structureless, fine, single grain.	Rapid	Structureless (hardpan).	Moderate	36	Rapid	Medium.
Basinger fine sand	8	4	do	do	Structureless, fine, single grain.	Rapid	40	Slow	Slow.
Pompano-Charlotte fine sand.	5	2	do	do	do	do	48	do	Do.
Placid fine sand	4	8	do	do	do	do	45	do	Do.
Adamsville fine sand	2	4	do	do	do	do	48	Moderate	Medium.
Felda, Pompano, Placid, Pamlico, ponded.	2	3	do	do	do	do	40	Slow	Slow.
Pomello find sand	1	4	do	Very rapid	do	Very rapid	60	Very rapid	Very rapid.
Delray fine sand	1	12	do	Rapid	do	Rapid	48	Slow	Slow.

[1]Soils: (Revision) Predominantly fine sand surface which is very friable and has above average infiltration rates and little surface runoff until it becomes saturated. Generally underlain at varying depths by organic hardpan or clay or marl layers of variable thickness and hardness. Slopes: 100 pct in 0-2 pct class. Erosion: Class 1-100 pct (Little or no erosion; small areas of plus deposition). Land Capability: Class and percent of area—I, zero pct; II, 3 pct; III, 9 pct; IV, 88 pct.

Source: Soil Survey of Okeechobee County, Florida (30). Percentages based on Okeechobee County averages.

Table A-3.—Monthly and annual precipitation, in inches, for Okeechobee hurricane gate 6

Year	Month												Annual
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1919	0.51	3.22	3.18	0.90	4.50	6.70	3.12	5.40	3.84	1.00	([1])	([1])	([2])
1920	([1])	([1])	([1])	([1])	2.91	4.67	9.62	3.72	9.70	([1])	([1])	([1])	([2])
1921	([1])	([1])	([1])	.21	5.07	2.23	5.30	4.33	.08	8.81	.84	1.31	([2])
1922	.49	.84	.34	0	3.81	9.97	6.41	5.20	9.72	8.06	.83	.58	46.25
1923	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])
1924	([1])	([1])	([1])	1.10	2.75	3.35	7.01	4.63	4.72	15.50	.38	.11	([2])
1925	4.31	.95	3.54	2.83	4.29	5.27	7.47	8.73	2.69	2.04	3.17	([1])	([2])
1926	([1])	1.53	1.56	6.13	2.56	7.90	9.75	7.29	6.01	1.72	1.97	21.1	([2])
1927	.54	.84	1.00	1.15	1.79	([1])	5.71	5.92	7.43	4.70	.60	.80	([2])
1928	.33	1.18	6.49	1.20	2.97	9.60	3.58	([1])	([1])	([1])	([1])	([1])	([2])
1929	([1])	([1])	.99	4.50	6.02	12.29	11.22	6.72	16.86	3.65	.30	([1])	([2])
1930	1.00	4.45	4.58	7.30	7.85	12.85	5.70	3.11	8.86	2.12	1.81	1.98	61.61
1931	1.97	1.17	2.98	7.71	2.59	1.28	2.97	4.85	4.75	2.42	.27	1.97	34.93
1932	1.14	.65	2.03	.73	7.52	8.81	2.94	12.45	4.08	3.62	1.81	([3])	45.78
1933	.71	.07	2.41	8.82	3.42	2.97	8.69	5.95	11.50	7.80	1.63	.35	54.42
1934	.76	2.47	4.37	4.37	6.69	9.46	6.01	4.41	6.40	2.75	.74	.71	49.16
1935	.39	2.94	.30	11:63	2.14	6.17	3.95	5.54	6.49	9.24	.72	1.95	51.46
1936	1.71	6.58	2.70	1.16	5.32	11.58	8.54	5.77	6.24	2.01	2.19	1.67	55.46
1937	.90	2.03	3.49	5.21	1.53	6.23	6.38	4.30	6.40	5.59	8.27	.63	50.96
1938	1.45	1.08	1.43	.55	2.02	10.46	10.08	1.27	7.17	5.06	2.42	.32	43.31
1939	.23	.23	2.60	6.36	8.48	7.21	7.93	8.95	5.38	4.10	2.59	2.14	56.20
1940	4.74	2.30	5.86	2.05	4.97	7.25	6.10	4.23	10.22	.30	0	4.95	52.97
1941	5.32	3.62	2.45	4.90	.90	3.83	12.82	2.24	3.90	6.95	1.95	4.54	53.42
1942	1.55	4.30	3.97	2.27	2.67	13.35	4.65	2.53	5.10	.70	.49	2.45	44.03
1943	0	1.30	4.60	1.74	4.90	2.26	6.77	8.20	4.00	3.60	3.67	.26	41.30
1944	.44	.25	1.87	6.98	2.72	5.02	3.98	4.56	3.14	7.03	.25	.14	36.38
1945	1.61	.25	1.90	4.29	1.47	5.04	4.78	5.37	11.32	5.17	1.31	.90	43.41
1946	1.48	1.02	1.34	.02	5.59	7.51	4.99	3.75	7.16	1.86	1.50	1.23	37.45
1947	.80	3.06	8.53	2.35	4.96	11.47	5.30	4.66	13.06	5.79	2.15	1.35	63.48
1948	4.48	0	.69	2.41	2.75	1.64	5.13	5.48	10.52	1.70	.37	.16	35.43
1949	.08	0	.04	4.00	4.02	11.09	8.11	9.69	8.21	1.96	.70	2.73	50.62
1950	.25	.28	3.58	1.42	.71	4.15	3.48	5.35	3.08	7.03	.69	.62	30.64
1951	0	2.30	.69	7.33	2.89	3.53	4.74	8.78	3.73	11.52	1.49	.12	47.12
1952	1.06	5.27	3.59	1.59	3.09	3.21	6.80	9.84	5.15	10.31	.11	.03	50.05
1953	2.12	2.04	3.36	3.57	1.83	9.05	4.95	10.49	8.36	7.81	.80	1.18	55.56
1954	.09	1.62	1.48	5.61	5.58	9.33	4.84	7.37	8.18	2.95	2.81	.82	50.68
1955	2.07	.59	1.77	3.11	.96	6.39	9.06	5.92	5.37	3.00	.30	2.46	41.00
1956	1.33	1.46	.20	3.37	5.22	3.70	4.13	9.00	5.14	15.13	.62	.42	49.72
1957	2.23	2.46	4.12	5.42	9.17	6.43	8.70	8.05	12.26	.98	.46	4.85	65.13
1958	6.17	1.00	5.21	2.27	5.75	3.34	2.13	4.39	5.80	2.24	.76	4.27	43.33
1959	1.97	.56	6.07	.72	5.37	13.56	4.72	5.36	7.20	7.25	3.60	1.40	57.78
1960	.20	3.12	3.99	2.32	2.79	10.77	6.73	5.67	14.55	3.35	2.19	.86	56.54
1961	1.93	.80	1.77	1.30	4.45	5.06	1.46	3.34	4.20	2.11	.33	.08	26.83
1962	.43	.26	4.08	1.93	2.70	12.00	8.56	8.43	5.71	1.33	4.17	.33	49.93
1963	.93	3.43	.94	.69	2.99	9.99	3.13	3.80	6.50	.42	2.87	4.28	39.97
1964	2.71	3.58	1.20	1.99	2.77	3.11	6.14	7.56	6.69	3.22	.36	1.41	40.72
1965	.34	4.99	2.89	2.03	.84	6.37	5.20	5.71	3.75	6.22	1.10	.95	40.39

1966	4.32	3.83	1.56	3.38	3.16	12.93	8.74	7.55	7.04	4.71	.28	.51	58.01
1967	1.22	2.64	.30	.17	.17	7.19	7.27	4.39	4.77	3.82	.07	1.13	33.14
1968	.46	2.01	.85	.29	6.75	16.47	6.99	2.81	7.32	5.07	1.57	0	50.59
1969	2.31	1.43	5.08	2.50	6.69	4.08	6.64	5.20	3.71	7.83	3.41	2.87	51.75
1970	4.92	3.14	7.21	(3)	4.83	8.48	7.21	7.12	4.39	6.61	.04	.87	54.82
1971	.32	.95	2.06	.48	2.49	8.01	5.74	5.45	(1)	(1)	(4)	....	......
	Mean												
	1.58	1.95	2.80	3.05	3.91	7.35	6.14	5.87	6.76	4.86	1.48	1.44	47.19
	Number of years												
	47	48	49	50	52	51	52	51	50	49	48	46	42

[1]Missing record.
[2]Partial annual data only are given.
[3]Trace.
[4]Discontinued.

Table A-4.—Monthly maximum daily rainfalls, in inches, for Okeechobee hurricane gate 6

	Month											
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1930	.65	2.00	1.90	2.65	2.70	2.00	2.00	1.10	2.00	1.05	1.50	.50
1931	.95	.75	.95	3.40	.82	.73	.73	.86	2.07	.70	.11	.74
1932	1.08	.35	.55	.33	3.82	3.40	1.05	2.40	1.40	1.35	.80	0
1933	.59	.03	1.05	5.29	1.30	.80	2.40	1.60	4.50	1.70	.55	.35
1934	.55	.65	2.25	1.60	2.58	2.20	1.19	1.94	2.30	.75	.30	.27
1935	.31	1.61	.30	3.55	1.65	2.30	1.45	1.88	2.00	2.30	.22	1.56
1936	.70	1.70	1.25	.97	1.65	4.30	1.12	1.20	1.60	.55	.85	.65
1937	.35	.67	2.30	1.95	.62	2.25	1.23	1.00	1.50	1.80	6.02	.60
1938	.80	.55	.80	.34	.80	1.56	3.45	.96	1.07	1.93	.64	.31
1939	.20	.10	1.64	2.25	3.03	2.14	1.75	3.69	1.45	2.10	1.80	.80
1940	1.90	1.00	1.50	1.10	2.90	1.70	1.65	1.15	2.00	.30	0	2.20
1941	1.85	1.83	1.10	1.25	.70	1.20	1.88	1.47	2.00	1.50	.30	2.00
1942	1.15	2.95	1.55	.95	.90	2.48	1.50	.60	1.70	.40	.15	.55
1943	0	.80	2.70	1.04	1.10	.70	1.80	2.30	1.75	1.05	2.63	.22
1944	.10	.26	.50	1.90	.95	2.60	1.10	1.08	.88	2.43	.15	.14
1945	1.10	.25	1.40	1.38	.95	1.82	1.55	1.36	3.72	2.20	.92	.35
1946	1.08	1.02	.92	.02	1.79	2.19	.96	1.04	1.40	1.32	1.46	.54
1947	.65	1.75	3.65	1.10	1.60	4.63	.87	1.69	3.34	1.88	.47	.86
1948	1.46	0	.35	1.15	1.42	.84	1.50	.76	3.14	.77	.20	.07
1949	.08	0	.04	1.13	2.20	3.23	1.52	6.50	2.09	.52	.52	.58
1950	.10	.12	1.79	1.27	.37	1.10	.97	1.09	1.04	4.93	.34	.37
1951	0	2.12	.61	2.56	1.19	.92	2.00	1.60	1.52	9.29	.68	.05
1952	.81	2.47	1.48	.83	1.29	1.49	1.96	2.28	1.46	4.11	.06	.03
1953	.80	.74	1.23	.93	1.30	2.25	1.76	3.63	1.43	2.00	.58	.38
1954	.04	.52	.60	1.24	1.18	2.31	1.33	1.83	1.35	1.00	1.09	.45
1955	1.61	.21	.97	1.08	.35	1.62	3.25	1.62	2.32	1.03	.27	1.70
1956	.98	.82	.20	1.45	1.58	1.23	1.75	2.59	1.03	5.07	.21	.23
1957	1.29	.90	1.38	1.37	3.74	1.09	1.43	2.14	1.95	.65	.21	3.73
1958	2.16	.46	1.56	.72	2.12	1.24	.60	1.00	1.39	1.07	.47	1.78
1959	.67	.30	1.79	.33	2.64	3.85	1.20	.95	2.35	2.14	1.81	.46
1960	.12	1.49	3.31	.88	1.03	4.08	1.33	.86	1.95	1.21	1.72	.52
1961	1.01	.33	1.26	.95	1.08	1.41	.56	.79	1.65	.58	.12	.05
1962	.18	.21	3.31	.94	1.55	2.77	3.06	4.10	2.17	.80	2.90	.11
1963	.43	1.50	.27	.64	1.22	2.90	1.48	1.35	1.90	.20	1.69	1.95
1964	.87	1.23	.71	.69	1.36	.95	1.28	3.75	1.88	.73	.21	.65
1965	.13	1.39	1.54	1.24	.76	1.74	1.22	1.14	.82	1.71	.30	.61
1966	1.11	1.55	.87	1.67	.78	2.37	1.91	1.58	1.31	1.48	.11	.18
1967	.37	1.56	.10	.16	.09	1.60	3.04	8.80	1.00	.93	.07	.88
1968	.18	.80	.32	.11	1.10	3.78	3.42	.90	1.72	1.42	1.30	0
1969	1.38	1.26	2.50	.94	2.09	2.45	2.22	1.21	.62	2.52	1.25	1.93
1970	1.26	1.95	2.93	([1])	2.69	1.74	2.49	2.90	.87	2.31	.04	.60
1971	.20	.37	.80	.42	1.97	1.45	1.86	1.26	2.33	1.53	.15	.76
1972	.26	1.03	.09	3.13	1.42	6.02	.84	2.69	.32	.17	.71	1.07
Maximum, 1930–72	2.16	2.95	3.65	5.29	3.82	6.02	3.45	8.80	4.50	9.29	6.02	3.73

[1]Trace.

Table A-5.—Monthly and annual rainfall, in inches, for watershed W-2

Year	Month												Annual
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1955	....	....	....	....	....	.....	5.00	5.32	3.88	2.83	0.18	2.40	19.61
1956	0.25	0.79	1.62	4.28	5.71	5.52	4.13	4.86	8.45	11.68	.18	.36	47.83
1957	1.53	3.80	4.34	5.64	7.45	4.94	6.98	9.26	10.59	1.20	.44	4.16	60.33
1958	6.05	1.00	6.15	1.74	3.81	5.24	6.82	7.45	5.36	3.48	.46	2.62	50.18
1959	3.26	.71	7.68	2.12	5.50	12.41	6.16	3.78	6.43	8.58	3.33	1.43	61.39
1960	.34	6.53	5.17	2.28	2.24	10.18	8.73	4.47	15.29	1.77	1.28	.74	59.02
1961	1.93	.85	1.58	1.24	4.51	4.30	3.94	5.97	1.79	3.05	1.07	.18	30.41
1962	.52	.38	3.72	2.19	5.82	11.20	7.72	9.34	6.53	1.22	2.29	.35	51.28
1963	.84	4.21	1.11	.76	4.76	5.44	3.14	3.49	7.34	.69	3.02	3.49	38.29
1964	1.69	3.44	.67	3.87	2.55	5.24	5.36	10.09	6.47	2.54	.85	1.78	44.55
1965	.26	3.17	3.20	1.17	1.01	6.79	7.47	4.33	4.81	4.16	.53	1.01	37.91
1966	6.04	3.09	.84	2.07	3.60	12.72	8.23	9.27	3.55	5.16	.46	.46	55.49
1967	.70	2.94	.89	.18	.11	13.27	8.44	10.70	5.29	3.62	.38	2.28	48.80
1968	.70	1.67	.65	.32	6.69	15.82	9.02	3.83	5.62	5.10	2.36	.12	51.90
1969	1.99	1.21	8.23	1.64	7.10	8.92	5.24	9.43	5.27	10.15	3.74	2.08	65.00
1970	4.81	2.66	6.88	.14	6.04	6.64	6.85	5.41	5.20	4.21	.06	.42	49.32
1971	.09	3.53	1.24	.38	5.50	11.67	6.91	6.18	5.85	5.13	.74	1.63	48.85
1972	.24	2.28	4.35	1.13	5.14	6.94	3.69	10.63	.84	1.62	3.26	1.71	41.83
1973	3.50	1.69	3.02	1.27	5.35	7.81	9.33	6.07	4.28	3.59	1.08	1.56	48.55
1974	1.26	.78	.10	3.01	4.35	9.64	11.41	7.37	4.74	1.49	1.25	1.42	46.82
1975	.40	2.04	.81	1.01	3.95	8.24	6.29	5.27	6.30	2.98	.50	.76	38.55
Average	1.82	2.34	3.11	1.82	4.56	8.65	6.71	6.79	5.90	4.01	1.31	1.47	[1]48.82

[1]1955 not included.

Table A-6.—Monthly and annual rainfall, in inches, for subwatershed W-3

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Month												
1955	....	....	....	....	....	.....	5.73	6.12	3.53	2.92	0.18	1.86	20.34
1956	0.39	1.04	1.11	6.20	3.93	4.78	2.73	6.64	8.30	13.50	.11	.12	48.85
1957	1.42	2.93	6.27	5.97	6.46	3.72	7.17	8.52	8.54	1.66	.28	3.69	56.63
1958	5.90	1.24	6.38	2.69	3.42	7.35	5.75	7.28	5.15	3.55	.58	2.50	51.79
1959	3.37	1.13	7.94	1.78	5.40	9.21	3.48	4.48	4.57	9.12	2.62	1.86	54.96
1960	.38	4.25	5.67	1.88	1.93	11.59	11.13	5.43	16.50	1.98	.77	.54	62.05
1961	1.80	1.21	2.03	1.77	4.21	4.77	4.70	4.80	2.73	1.70	.65	.25	30.62
1962	.65	.59	2.93	1.75	5.06	9.18	7.89	10.77	6.86	1.06	2.99	.34	50.07
1963	.80	4.17	1.30	.80	5.67	5.95	5.10	1.85	8.64	1.40	3.09	3.06	41.83
1964	1.70	3.38	1.08	3.06	3.79	5.43	4.24	11.64	6.30	2.43	.54	2.64	46.23
1965	.16	2.91	2.88	.82	.87	5.05	8.91	4.48	4.80	3.62	.29	1.56	36.35
1966	5.23	3.25	.61	1.42	2.40	11.76	8.54	8.41	3.59	3.52	.52	.42	49.67
1967	.50	3.12	.40	.29	.01	12.76	8.11	7.96	4.70	3.52	.59	2.42	44.38
1968	.37	1.48	.64	.23	7.14	12.38	10.25	4.46	3.89	5.20	2.66	.14	48.84
1969	1.88	1.33	8.24	2.16	5.29	7.06	4.73	10.48	3.64	9.39	3.10	1.58	58.88
1970	4.58	2.84	6.43	.02	6.92	6.28	5.25	4.04	6.87	2.57	.03	.43	46.26
1971	.05	5.19	1.17	.67	5.59	10.75	6.72	7.33	5.28	7.08	.36	1.33	51.52
1972	.38	1.81	3.83	1.07	4.79	8.54	3.81	12.58	1.47	1.13	3.68	1.41	44.50
1973	3.39	2.09	3.24	1.11	4.51	7.39	10.90	4.91	5.28	2.81	1.71	1.67	49.01
1974	1.56	1.16	.10	3.83	3.08	10.14	9.83	7.41	5.91	1.18	.99	1.70	46.89
1975	.60	1.68	1.02	1.13	3.16	7.84	7.24	6.58	5.18	4.79	.41	.89	40.52
Average	1.76	2.34	3.16	1.93	4.18	8.10	6.77	6.96	5.80	4.01	1.25	1.45	[1]47.99

[1]1955 not included.

Table A-7.—Monthly and annual rainfall, in inches, for subwatershed W-5

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Month												
1964	....	....	....	5.01	1.91	5.19	6.24	9.58	6.77	2.89	1.15	1.32	40.06
1965	0.37	3.62	3.49	.83	.93	7.30	6.37	3.00	4.63	5.18	.56	.76	37.04
1966	6.48	3.19	1.06	2.84	5.09	12.98	8.18	10.80	4.50	5.90	.37	.56	61.95
1967	.84	2.54	.94	0	.23	12.56	11.38	12.39	5.38	3.72	.41	2.26	52.65
1968	1.10	1.85	.75	.44	5.46	18.04	7.74	3.50	7.69	5.73	2.04	.08	54.42
1969	2.02	1.16	7.82	.77	8.20	10.54	6.01	9.74	7.36	10.44	4.03	2.78	70.87
1970	4.68	2.93	7.17	.23	5.20	7.69	8.13	7.81	4.84	5.56	.07	.45	54.76
1971	.13	2.11	.99	.27	4.87	11.51	6.02	5.46	6.58	4.58	1.26	2.20	45.98
1972	.20	2.70	4.88	1.37	4.06	6.34	3.25	9.82	.45	2.24	3.02	1.64	39.97
1973	3.31	1.56	2.92	1.37	6.21	7.40	9.68	5.60	4.47	3.90	.40	1.35	48.17
1974	.82	.68	.16	1.95	5.49	9.04	10.96	7.38	4.34	1.64	1.31	1.36	45.13
1975	.22	2.48	.68	.61	5.78	8.63	5.84	4.43	7.00	2.16	.52	.65	36.03
Average	1.83	2.26	2.80	1.31	4.45	9.77	7.48	7.46	5.33	4.50	1.26	1.28	[1]49.72

[1]1964 not included.

Table A-8.—Monthly and annual maximum rainfall, in inches, by selected time intervals, rain-gage 3, 1961–75

	1-hour[1]		2-hour[1]		6-hour[1]		12-hour[1]		24-hour[1]	
	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount
1961										
November	20	0.95	20	0.95	20	0.95	20	0.95	20	0.95
December	27	.07	27	.07	27	.07	27	.07	27	.07
1962										
January	6	0.23	6	0.23	6	0.23	6	0.23	6	0.23
February	10	.26	10	.26	10	.36	10	.36	10	.36
March	30	2.44	30	2.45	30	4.45	30	4.45	30	4.45
April	26	.81	26	.83	26	.91	26	.91	26	.91
May	21	1.22	26	1.32	4	1.96	4	2.04	4	2.06
June	29	.92	29	1.62	29	1.72	29	1.72	29	2.29
July	13	1.50	11	1.63	11	2.60	11	2.60	11	2.60
August	28	1.60	28	1.60	28	1.60	28	1.60	27	2.75
September	20	.58	20	.84	20	1.32	20	1.98	20	2.81
October	1	.85	3	1.20	3	1.33	3	1.33	3	1.33
November	8	.30	8	.54	8	.97	8	1.73	8	2.05
December	9	.12	9	.12	9	.12	9	.12	9	.12
Annual maximum	Mar. 30	2.44	Mar. 30	2.45	Mar. 30	4.45	Mar. 30	4.45	Mar. 30	4.45
1963										
January	21	0.22	21	0.27	21	0.28	21	0.28	21	0.28
February	19	.90	26	1.01	26	1.62	26	1.62	26	1.62
March	9	.18	9	.18	9	.18	9	.18	9	.18
April	30	.38	25	.50	25	.50	25	.50	25	.50
May	25	.56	31	.80	31	.92	3	1.32	3	1.32
June	4	1.11	4	1.50	4	1.50	4	1.50	4	2.25
July	28	.60	28	.60	28	.60	28	.60	28	.60
August	12	.82	12	.82	12	.82	12	.82	12	.82
September	14	1.00	14	1.20	14	1.20	14	1.20	14	1.39
October	14	.20	14	.28	14	.28	14	.28	14	.28
November	10	1.25	10	1.45	10	1.76	10	2.11	10	2.17
December	30	.23	30	.44	30	.83	30	1.16	30	1.57
Annual maximum	Nov. 10	1.25	June 4	1.50	Nov. 10	1.76	Nov. 10	2.11	June 4	2.25

See footnotes at end of table.

Table A-8.—Monthly and annual maximum rainfall, in inches, by selected time intervals, rain-gage 3, 1961–75—Continued

	1-hour[1]		2-hour[1]		6-hour[1]		12-hour[1]		24-hour[1]	
	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount
					1964					
January	7	0.27	7	0.30	7	0.66	7	0.69	7	0.69
February	8	.19	8	.29	5	.83	5	1.06	5	1.34
March	28	.55	28	.60	28	.60	28	.60	28	.60
April	5	1.10	5	1.12	24	1.60	24	1.60	24	1.60
May	1	.68	1	.88	1	1.06	1	1.10	2	1.26
June	9	1.50	9	2.10	9	2.14	9	2.14	9	2.14
July	7	1.39	7	1.39	7	1.47	7	1.47	7	1.47
August	20	1.18	20	1.96	20	2.25	27	4.29	27	4.35
September	16	1.55	13	1.64	13	2.03	13	2.03	12	2.33
October	1	.89	1	.89	1	.95	1	.95	1	1.00
November	23	.26	23	.38	23	.38	23	.38	23	.38
December	4	.97	4	1.12	4	1.20	4	1.20	4	1.20
Annual maximum	Sept. 16	1.55	June 9	2.10	Aug. 20	2.25	Aug. 27	4.29	Aug. 27	4.35
					1965					
January	22	0.07	22	0.12	1	0.23	1	0.23	1	0.23
February	23	.71	23	.87	23	1.07	23	1.32	22	1.69
March	27	.62	27	.77	27	.82	27	.82	26	.99
April	26	1.20	26	1.20	26	1.55	26	1.55	26	1.55
May	24	.98	24	1.43	24	1.63	24	1.68	24	1.68
June	18	1.25	18	1.90	18	2.17	18	2.17	18	2.20
July	11	1.10	12	1.45	12	1.45	11	1.73	11	2.10
August	8	.78	8	.93	8	.97	8	.97	8	1.32
September	30	1.50	30	1.70	30	1.75	30	1.75	30	1.75
October	14	.25	14	.40	14	.73	14	.90	14	.95
November	6	.15	6	.15	30	.15	5	.21	5	.21
December	20	.24	20	.44	19	.60	19	.60	19	.60
Annual maximum	Sept. 30	1.50	June 18	1.90	June 18	2.17	June 18	2.17	June 18	2.20
					1966					
January	4	0.65	4	1.26	4	2.32	4	2.57	4	2.87
February	23	.75	23	.95	19	1.18	19	1.18	22	2.08
March	5	.20	5	.20	29	.48	29	.53	29	.54
April	4	.55	4	.62	4	.86	4	.01	4	1.08
May	11	.41	11	.57	11	.85	11	.85	11	.85
June	6	2.23	6	2.44	6	2.50	6	2.50	8	2.85
July	26	1.40	26	1.45	26	1.48	26	1.48	26	1.51
August	18	.95	18	.95	18	.95	18	.95	8	1.16
September	10	.68	10	.68	10	.77	10	.77	10	.95
October	7	1.97	7	2.71	7	2.91	7	2.91	7	2.96
November	23	.16	23	.16	23	.33	23	.33	23	.33
December	4	.15	4	.20	4	.28	4	.28	4	.28
Annual maximum	June 6	2.23	Oct. 7	2.71	Oct. 7	2.91	Oct. 7	2.91	Oct. 7	2.96

	1-hour[1]		2-hour[1]		6-hour[1]		12-hour[1]		24-hour[1]	
	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount
1967										
January	25	0.80	25	0.80	25	0.80	25	0.80	25	0.80
February	21	.29	21	.49	21	.98	21	1.28	21	1.62
March	8	.37	8	.45	8	.54	8	.90	8	.92
April	19	.10	19	.10	19	.10	19	.10	19	.10
May	22	.09	22	.09	22	.09	22	.09	22	.10
June	23	2.15	23	2.56	23	2.60	23	2.60	23	2.60
July	13	.83	13	.93	13	1.16	13	1.17	13	1.21
August	30	1.55	30	2.75	30	2.80	30	2.80	30	2.80
September	13	1.06	13	1.22	13	1.31	13	1.47	28	1.54
October	24	1.22	24	1.71	24	2.06	24	2.25	24	2.26
November	16	.08	16	.12	16	.13	16	.13	16	.13
December	11	.70	11	1.37	11	1.37	11	1.37	11	1.40
Annual maximum	June 23	2.15	Aug. 30	2.75	Aug. 30	2.80	Aug. 30	2.80	Aug. 30	2.80
1968										
January	10	0.18	10	0.18	10	0.18	10	0.18	10	0.18
February	19	.23	19	.41	19	.85	18	1.02	18	1.05
March	6	.24	6	.37	6	.54	6	.55	6	.55
April	15	.18	15	.18	15	.18	15	.18	15	.18
May	19	1.22	19	1.51	19	1.59	19	1.64	19	1.64
June	16	.98	13	1.60	13	2.19	13	2.65	3	2.85
July	2	1.54	2	1.91	2	2.01	2	2.03	1	2.43
August	8	1.00	8	1.00	8	1.00	8	1.00	8	1.00
September	19	1.87	19	2.12	19	2.15	19	2.15	19	2.15
October	17	.80	15	1.37	15	1.92	15	2.05	15	2.05
November	9	.71	9	1.11	9	1.77	9	1.87	9	1.88
December	28	.06	28	.10	28	.12	28	.12	28	.12
Annual maximum	Sept. 19	1.87	Sept. 19	2.12	June 13	2.19	June 13	2.65	June 3	2.85
1969										
January	4	0.65	4	0.80	4	1.25	4	1.40	4	1.40
February	15	.58	15	.99	15	1.04	15	1.04	15	1.04
March	8	2.11	8	2.77	8	3.11	8	4.75	8	5.21
April	2	.41	2	.75	2	.75	2	.75	2	.75
May	14	1.32	14	1.53	3	2.06	3	2.15	3	2.15
June	12	1.14	12	1.55	12	2.40	12	2.42	12	2.45
July	18	2.51	18	3.02	18	3.34	18	3.37	18	3.62
August	13	.75	13	.82	4	1.01	15	1.23	15	1.27
September	24	.76	24	.76	18	.80	18	.83	18	.88
October	2	1.05	2	1.13	2	2.81	2	4.28	2	4.43
November	13	.94	14	.95	14	2.05	13	2.20	13	3.14
December	10	1.16	10	1.26	10	1.63	10	1.63	10	1.63
Annual maximum	July 18	2.51	July 18	3.02	July 18	3.34	Mar. 8	4.75	Mar. 8	5.21

See footnotes at end of table.

Table A-8.—Monthly and annual maximum rainfall, in inches, by selected time intervals, rain-gage 3, 1961–75—Continued

	1-hour[1]		2-hour[1]		6-hour[1]		12-hour[1]		24-hour[1]	
	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount
					1970					
January	6	1.05	6	1.25	6	1.70	15	1.90	15	1.90
February	3	1.01	3	1.35	3	1.64	3	1.64	3	1.64
March	26	.70	26	.92	25	1.70	25	2.45	26	4.13
April	3	.15	3	.15	3	.15	3	.15	3	.15
May	27	2.02	27	3.39	27	3.46	27	3.46	27	3.49
June	25	.62	25	1.20	25	1.35	25	1.40	24	1.57
July	21	1.25	21	2.25	21	2.96	21	2.96	21	2.99
August	24	1.73	24	1.82	24	1.82	24	1.82	24	1.83
September	14	.66	14	1.06	29	1.36	29	1.60	29	1.82
October	2	1.18	2	2.08	2	2.11	2	2.12	2	2.14
November	10	.07	10	.07	10	.07	10	.07	10	.07
December	17	.21	17	.22	17	.23	17	.23	17	.23
Annual maximum	May 27	2.02	May 27	3.39	May 27	3.46	May 27	3.46	Mar. 26	4.13
					1971					
January	18	0.02	18	0.03	19	0.06	19	0.08	19	0.08
February	23	1.71	23	2.34	23	2.93	23	2.93	22	2.98
March	13	.46	13	.46	13	.46	13	.46	13	.46
April	4	.12	4	.12	4	.12	4	.12	4	.15
May	28	1.98	28	2.37	28	2.52	28	2.52	15	3.25
June	17	2.09	17	3.14	17	4.30	17	4.30	17	4.33
July	9	1.20	9	1.80	9	1.95	9	1.95	9	1.95
August	4	.41	4	.61	13	.68	13	1.52	13	1.66
September	2	.60	2	1.00	2	1.47	2	1.55	2	1.73
October	5	1.05	5	1.05	9	1.25	9	1.25	9	1.33
November	5	.15	5	.15	5	.17	5	.17	5	.17
December	3	.40	3	.46	3	.70	3	.70	3	.70
Annual maximum	June 17	2.09	June 17	3.14	June 17	4.30	June 17	4.30	June 17	4.33
					1972					
January	31	0.10	31	0.10	31	0.10	31	0.10	31	0.11
February	3	.14	3	.24	9	.30	9	.65	9	.66
March	31	1.08	31	1.69	31	3.09	31	3.09	31	3.09
April	9	.36	9	.39	9	.40	9	.40	9	.40
May	12	.81	12	1.39	12	1.48	12	1.48	20	1.76
June	18	1.12	18	1.20	18	2.21	18	3.33	18	4.56
July	13	.82	13	.89	13	1.00	13	1.00	13	1.03
August	8	1.45	8	1.45	8	1.45	8	1.45	8	1.45
September	1	.20	1	.20	1	.20	1	.20	1	.20
October	4	.30	4	.60	4	.85	4	.85	4	.85
November	19	.42	19	.78	19	.80	19	.80	19	1.10
December	22	.90	22	1.03	22	1.10	22	1.13	22	1.13
Annual maximum	Aug. 8	1.45	Mar. 31	1.69	Mar. 31	3.09	June 18	3.33	June 18	4.56

	1-hour[1]		2-hour[1]		6-hour[1]		12-hour[1]		24-hour[1]	
	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount	Date[2]	Amount
1973										
January	27	0.61	27	0.70	27	0.74	27	0.85	27	0.85
February	9	.50	9	1.00	9	1.18	9	1.18	9	1.18
March	26	.63	25	1.13	25	2.59	25	2.69	25	2.69
April	8	.46	8	.61	8	1.01	8	1.01	8	1.01
May	25	.60	25	.80	9	1.23	9	1.90	9	1.90
June	20	.75	20	.79	20	1.75	20	1.75	20	2.15
July	8	1.15	10	1.27	10	1.42	10	1.42	10	1.42
August	20	1.25	11	1.48	11	2.10	11	2.10	24	2.35
September	2	.75	2	.90	2	1.00	2	1.00	2	1.02
October	18	.53	18	.53	18	.60	18	1.07	18	1.33
November	1	.49	1	.94	1	1.16	1	1.16	1	1.16
December	16	.55	20	.65	20	.77	20	.82	20	.82
Annual maximum	Aug. 20	1.25	Aug. 11	1.48	Mar. 25	2.59	Mar. 25	2.69	Mar. 25	2.69
1974										
January	29	0.79	29	1.29	29	1.29	29	1.29	29	1.29
February	16	.48	16	.48	16	.48	16	.48	16	.48
March	15	.03	15	.05	15	.05	15	.05	15	.05
April	16	1.29	16	2.16	16	2.16	16	2.16	16	2.16
May	29	1.70	29	1.81	29	1.81	29	1.81	29	1.81
June	25	1.46	25	2.18	25	3.20	25	4.15	24	4.85
July	22	2.19	22	2.48	22	2.68	22	2.68	22	2.72
August	19	1.45	5	1.50	5	1.60	5	1.60	5	1.85
September	30	.74	30	1.25	30	1.63	30	1.63	30	1.63
October	6	.45	6	.88	6	.96	6	1.22	6	1.29
November	27	.21	27	.30	27	.35	27	.61	27	.67
December	16	.25	16	.34	16	.47	16	.67	16	.74
Annual maximum	July 22	2.19	July 22	2.48	June 25	3.20	June 25	4.15	June 24	4.85
1975										
January	24	0.35	24	0.44	24	0.45	24	0.45	24	0.46
February	10	.36	10	.68	10	.96	10	1.03	10	1.03
March	5	.18	5	.28	5	.33	5	.34	5	.34
April	11	.51	11	.69	11	.72	11	.73	11	.73
May	28	.85	28	.95	28	1.03	28	1.09	28	1.10
June	20	1.34	20	1.37	9	1.40	20	1.43	20	1.44
July	1	.80	1	.81	1	.81	12	1.48	12	1.87
August	19	.63	19	.89	8	[3]1.15	8	[3]1.30	8	[3]1.30
September	1	.94	1	.99	3	1.04	3	1.04	3	1.49
October	29	.84	29	.92	29	.95	28	1.17	28	1.30
November	20	.08	19	.09	19	.10	19	.11	19	.21
December	20	.14	20	.26	20	.48	20	.51	20	.53
Annual maximum	June 20	1.34	June 20	1.37	June 9	1.40	July 12	1.48	July 12	1.87

[1]Determined from clock hour values by hourly increments.
[2]Date rainfall began if rainfall occurred over 2 calendar days.
[3]Estimated.

Table A-9.—Monthly maximum daily rainfall, in inches, for rain-gage 3

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1955	....	....	....	....	....	....	....	....	....	1.77	0.12	1.09
1956	0.00	0.80	2.12	2.13	1.67	1.02	1.53	1.45	[1]3.80	4.70	.03	.27
1957	.86	.83	1.41	2.39	1.07	1.11	1.72	[1]3.04	2.08	.43	.16	2.91
1958	1.76	.64	3.40	.63	2.28	2.07	1.83	1.84	1.28	1.14	[1] .40	[1]1.88
1959	2.26	.18	1.88	[1]1.17	2.37	4.60	1.10	.59	1.25	2.90	1.88	.90
1960	.30	3.47	2.94	[1]1.22	.55	2.21	2.59	1.22	2.35	.65	1.25	.54
1961	[1]1.12	.43	.87	1.00	[1]2.66	1.01	1.04	.91	.47	2.00	[1] .95	.07
1962	.23	.36	[1]4.45	.91	2.04	1.72	2.60	2.60	[1]2.50	[1]1.33	1.85	.12
1963	.28	1.62	.25	.50	1.32	1.50	.60	.82	1.20	.28	2.13	1.52
1964	.69	1.34	.60	1.60	1.10	2.14	1.47	4.35	[1]2.03	[1] .95	.38	1.20
1965	.23	1.57	.82	[1]1.55	[1]1.68	2.17	1.75	.97	[1]1.75	.95	.21	.45
1966	2.82	1.70	.54	1.00	.85	2.70	1.48	1.16	.75	[1]2.91	[1] .33	.28
1967	[1] .80	1.32	.90	.10	.09	2.60	.83	2.80	1.47	[1]2.25	.13	1.37
1968	.18	[1]1.00	.55	.18	1.64	2.85	2.03	1.00	[1]2.15	[1]2.05	[1]1.88	.12
1969	[1]1.40	1.04	[1]4.25	.75	2.15	2.45	[1]3.35	1.23	.88	[1]3.76	[1]2.29	1.63
1970	[1]1.90	1.64	2.45	.15	3.46	1.35	[1]2.96	1.82	1.59	2.10	.07	.23
1971	[1] .08	2.93	.46	.12	[1]2.95	4.30	1.95	1.55	1.73	1.25	.17	.70
1972	.06	.66	3.09	.40	1.76	3.76	1.00	1.45	.20	.85	.80	1.13
1973	[1] .85	1.00	[1]2.00	1.01	1.90	1.75	1.42	[1]2.35	1.00	.90	1.16	.82
1974	[1]1.25	..48	.05	[1]2.16	1.81	[1]4.85	2.68	1.60	1.65	[1]1.40	.73	.69
1975	.49	1.13	.35	.73	[1]1.09	[1]1.45	[1]1.87	1.44	1.03	.95	.12	.34
Maximum, 1955–75...........	2.82	3.47	4.45	2.39	3.46	4.85	3.35	4.35	3.80	4.70	2.29	2.91

[1]Value is maximum of 7 gages.

Table A-10.—Upper Taylor Creek watershed improvement works

Phase and date	Description
Phase I:	
Begin June 1962	Construction of structure No. 1 (S-1) main channel.
End September 1962	Construction of main structure, Williamson Ditch.
Phase II:	
Begin February 1964	Main channel improvement.
	Popash Slough improvement.
	Williamson Ditch main ditch improvement.
	Williamson Ditch east lateral improvement.
	Otter-Biminy Creek improvement.
	Structure No. 2, main channel: radial gate, 50 ft wide, elevation 20.40 ft above m.s.l.; gate closed, elevation 24.00 ft above m.s.l.
	Structure No. 3, main channel: radial gate, 10 ft wide, elevation 27.57 ft above m.s.l.; gate closed, elevation 30.57 ft above m.s.l.
	Structure No. 8, Williamson Ditch: weir 12 ft wide, elevation 29.09 ft above m.s.l.
	Pipe-arch drop spillways:
	Popash Slough: 50 by 31 inches, 1 pipe, bottom elevation 24.02 ft above m.s.l.
	Williamson Ditch: 50 by 31 inches, 2 pipes, bottom elevation 34.00 ft above m.s.l.
End October 1964	Main channel: 50 by 36 inches, 2 pipes, bottom elevation 34.00 ft above m.s.l.
Unscheduled	Main channel extended on north end, increasing W-3 and W-2 drainage area.
(performed by private landowner in 1966).	Channel improvement on west side, increasing W-2 drainage area.
Phase III:	
Begin August 1967	Williamson Ditch east lateral improvement.
	Otter Creek channel improvement.
	Little Biminy Creek channel improvement.
	East Otter Creek channel improvement.
	Structure No. 9, Williamson Ditch east lateral:
	pipe-arch drop spillway, 48 inches, 3 pipes, bottom elevation 28.06 ft above m.s.l.
	Structure No. 13, Otter Creek: weir 15 ft wide, elevation 34.07 ft above m.s.l.
	Structure No. 13A, Otter Creek: weir 18 ft wide, elevation 45.17 ft above m.s.l.
	Structure No. 13B, Otter Creek: weir 9 ft wide, elevation 54.39 ft above m.s.l.
	Structure No. 13C, Otter Creek: weir 11.5 ft wide, elevation 59.00 ft above m.s.l.
	Structure No. 14, east Otter Creek: weir 9 ft wide, elevation 35.98 ft above m.s.l.
End June 1968	Structure No. 15, east Otter Creek: weir 9 ft wide, elevation 43.87 ft above m.s.l.

Table A-11.—Monthly and annual streamflow, in inches, for watershed W-2

	Month												
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1955	....	....	....	....	....	....	1.35	1.41	1.44	0.36	0.03	0.04	4.63
1956	0.04	0.01	0	0	0.66	0.28	.30	.02	2.64	9.80	.22	.04	14.01
1957	.06	.07	.71	.91	2.24	1.48	2.48	5.26	6.37	1.45	.09	.26	21.38
1958	2.50	.46	1.89	.44	.17	.09	2.16	1.73	1.19	.49	.14	.13	11.39
1959	.48	.30	3.30	.32	.16	9.31	1.42	.75	2.76	4.56	1.92	.40	25.68
1960	.25	2.86	3.54	.30	.09	2.79	2.20	4.20	10.80	4.09	.26	.03	31.41
1961	.12	.04	.02	.01	.01	.07	.06	.09	.10	.03	.03	.01	.59
1962	.02	.02	.03	.08	.10	1.58	5.98	2.94	6.20	.58	.13	.09	17.75
1963	.08	.29	.19	.03	.03	.13	.09	.03	.36	.29	.13	.10	1.75
1964	.57	.81	.06	.11	.18	.11	.26	2.61	3.94	.27	.07	.14	9.13
1965	.07	.12	.18	.07	.03	.19	.37	.46	.21	.36	.25	.08	2.39
1966	.77	.81	.25	.15	.29	2.18	3.15	4.70	.75	1.83	.15	.14	15.17
1967	.11	.15	.13	.05	.02	.50	4.00	3.10	2.18	1.33	.19	.15	11.91
1968	.15	.11	.09	.03	.14	7.84	5.76	.79	1.57	2.15	.85	.18	19.66
1969	.26	.15	4.14	.25	1.56	5.88	.80	4.42	1.62	5.66	3.17	1.23	29.14
1970	2.84	1.10	3.46	.33	.34	.94	2.31	1.08	.35	1.42	.23	.15	14.55
1971	.13	.21	.14	.05	.10	2.69	2.42	2.24	3.80	.95	.38	.20	13.31
1972	.14	.16	.16	.32	.16	1.08	.35	.99	1.73	.21	.14	.15	5.59
1973	.30	.38	.31	.13	.14	.79	2.71	1.71	1.32	1.06	.25	.08	9.18
1974	.08	.06	.03	.11	.02	.83	6.83	4.58	.79	.83	.05	.07	14.28
1975	.08	.07	.01	.06	.01	.12	.44	.42	1.20	.72	.16	.04	3.33
Average	0.45	0.41	0.93	0.19	0.32	1.94	2.16	2.07	2.44	1.83	0.42	0.18	[1]13.58

[1]1955 not included.

Table A-12.—Monthly and annual streamflow, in inches, for subwatershed W-3

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Month												
1955	....	....	....	....	....	....	....	....	....	0.29	0.02	0.02	0.33
1956	0.04	0.02	0.01	0.16	1.14	0.04	0.05	0.09	3.30	9.19	.08	.02	14.14
1957	.04	.04	.55	.85	.78	.90	1.12	3.43	5.45	.95	.01	.16	14.28
1958	2.27	.29	2.10	.62	.17	.08	1.59	.85	.76	.59	.06	.07	9.45
1959	.48	.17	3.35	.17	.45	5.78	.16	.39	.41	6.10	.59	.44	17.99
1960	.10	.97	3.58	.08	.01	2.72	4.54	1.92	10.93	1.53	.11	.03	26.52
1961	.06	.03	.02	.02	.01	.13	.06	.05	.06	.02	.01	.01	.48
1962	.01	0	.03	.03	.18	.77	3.10	4.78	5.17	.45	.13	.03	14.68
1963	.02	.12	.13	.01	.01	.14	.15	.02	.93	.22	.18	.10	2.03
1964	.56	1.06	.01	.03	.11	.06	.12	3.36	4.75	.32	.06	.15	10.59
1965	.03	.05	.19	.05	0	.09	.58	1.13	.42	.48	.28	.17	3.47
1966	.87	1.05	.12	.04	0	.80	2.36	3.62	.50	1.83	.09	.03	11.31
1967	.02	.06	.05	0	0	1.28	4.03	2.74	1.52	.58	.24	.14	10.66
1968	.06	.05	.03	0	.02	4.42	7.25	1.66	.45	1.25	.95	.11	16.25
1969	.19	.09	2.90	.29	1.01	4.00	.42	3.91	.53	4.31	2.60	.60	20.85
1970	2.24	.91	2.95	.35	.23	.68	.67	.40	.58	1.02	.15	.06	10.24
1971	.06	.24	.14	.04	.04	2.31	1.42	3.18	3.64	1.74	.42	.20	13.43
1972	.15	.18	.10	.12	.14	.74	.17	1.37	1.93	.12	.18	.14	5.34
1973	.30	.41	.71	.21	.20	.41	4.89	2.86	2.03	.80	.66	.22	13.70
1974	.12	.07	.03	.13	([1])	.97	8.06	4.67	1.98	1.32	.02	.03	17.40
1975	.02	.05	.01	0	0	.20	.58	.67	1.00	1.45	.71	.11	4.80
Average	0.38	0.29	0.85	0.16	0.22	1.33	2.07	2.06	2.32	1.65	0.36	0.14	[2]11.88

[1]Trace.
[2]1955 not included.

Table A-13.—Monthly and annual streamflow, in inches, for subwatershed W-5

Year	Month												Annual
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1964	....	....	....	0.17	0.21	0.18	0.50	2.88	4.56	0.48	0.15	0.21	9.34
1965	0.12	0.24	0.26	.13	.06	.26	.30	.24	.15	.44	.29	.12	2.61
1966	1.14	.93	.32	.24	.83	2.96	4.45	6.64	1.50	2.32	.20	.15	21.68
1967	.14	.14	.13	.09	.06	.21	5.57	3.00	1.78	1.47	.14	.12	12.85
1968	.15	.15	.11	.08	.11	9.52	4.90	.42	2.71	3.59	.72	.16	22.62
1969	.27	.14	3.17	.16	1.05	5.00	.97	5.28	3.05	5.64	3.10	1.87	29.70
1970	3.07	1.15	3.81	.33	.29	1.32	3.51	2.44	.39	1.98	.27	.12	18.68
1971	.11	.15	.15	.08	.14	1.81	2.03	1.51	4.04	.39	.49	.18	11.08
1972	.13	.18	.24	.51	.08	1.00	.19	.78	.74	.11	.12	.15	4.23
1973	.27	.26	.18	.10	.16	1.33	1.86	1.75	1.20	1.63	.15	.11	9.00
1974	.10	.08	.08	.06	.04	.77	6.66	4.00	.70	.79	.09	.12	13.49
1975	.09	.15	.06	.06	.05	.33	.66	.26	1.72	.66	.12	.12	4.28
Average	0.51	0.32	0.77	0.17	0.26	2.06	2.63	2.43	1.88	1.62	0.49	0.29	[1]13.66

[1]1964 not included.

Table A-14.—Annual maximum peak discharge rates and volumes by selected time intervals, watershed W-2

Year	Peak discharge rate (inch/hour)	Maximum volume (inches) for T						
		1 hour	2 hours	6 hours	12 hours	1 day	2 days	8 days
1956	0.110	0.110	0.210	0.620	1.23	2.28	4.16	8.03
1957	.015	.015	.030	.090	.180	.340	.669	2.19
1958	.013	.013	.026	.076	.148	.293	.558	1.60
1959	.070	.070	.139	.412	.810	1.60	3.08	7.16
1960	.037	.037	.074	.219	.430	.840	1.64	5.18
1961	.001	.001	.002	.005	.009	.016	.026	.072
1962	.021	.021	.042	.125	.248	.480	.920	2.61
1963	.004	.004	.007	.021	.041	.075	.143	.372
1964	.038	.038	.074	.220	.420	.825	1.44	2.58
1965	.003	.003	.006	.017	.033	.065	.110	.223
1966	.024	.024	.048	.142	.284	.550	1.01	2.06
1967	.021	.021	.042	.125	.246	.465	.830	1.68
1968	.028	.028	.057	.170	.338	.671	1.19	3.64
1969	.029	.029	.058	.174	.341	.841	1.54	4.77
1970	.037	.037	.074	.221	.435	.813	1.55	2.78
1971	.028	.028	.057	.168	.335	.378	.624	1.72
1972	.024	.024	.049	.147	.284	.422	.566	1.78
1973[1]	....	.....	......	......	....	.266	.395	.04
1974[1]	....	.....	......	......	....	.485	.868	2.91
1975[1]	....	.....	......	......	....	.114	.223	.575
Maximum 1956–75	0.110	0.110	0.210	0.620	1.23	2.28	4.16	8.03

[1]Values for peak discharge and volume for 1-, 2-, 6-, and 12-hour time intervals are indeterminable.

Table A-15.—Annual maximum peak discharge rates and volumes by selected time intervals, subwatershed W-3

Year	Peak discharge rate (inch/hour)	Maximum volume (inches) for T						
		1 hour	2 hours	6 hours	12 hours	1 day	2 days	8 days
1956	0.250	0.240	0.470	1.35	2.55	3.14	6.21	8.67
1957	.058	.058	.116	.336	.633	1.09	1.63	3.16
1958	.029	.029	.057	.166	.320	.559	.852	1.65
1959	.094	.094	.183	.538	.998	1.70	2.97	4.57
1960	.083	.083	.166	.486	.912	1.66	2.30	4.35
1961	.003	.003	.005	.015	.028	.041	.058	.083
1962	.035	.035	.070	.204	.400	.770	.992	2.78
1963	.013	.013	.026	.076	.150	.250	.497	.910
1964	.064	.064	.126	.372	.720	1.27	1.99	3.53
1965	.012	.012	.022	.063	.120	.228	.384	.755
1966	.018	.018	.035	.102	.200	.384	.602	1.34
1967[1]	....	.....	......	......	....	.970	1.55	2.51
1968	.073	.073	.147	.441	.871	1.45	2.02	4.21
1969	.073	.073	.146	.439	.760	1.33	1.90	2.79
1970	.075	.075	.148	.441	.838	1.05	1.94	2.36
1971	.045	.043	.073	.195	.367	.570	1.05	1.88
1972	.034	.034	.068	.202	.388	.755	1.16	2.60
1973	.049	.049	.098	.272	.499	.626	.894	2.09
1974	.088	.087	.173	.508	.935	1.39	1.68	3.67
1975	.011	.011	.024	.071	.140	.210	.416	.918
Maximum, 1956–75.	0.250	0.240	0.470	1.35	2.55	3.14	6.21	8.67

[1]Values for peak discharge and volume for 1-, 2-, 6-, and 12-hour time intervals are indeterminable.

Table A-16.—Annual maximum peak discharge rates and volumes by selected time intervals subwatershed W-5

Year	Peak discharge rate (in/h)	Maximum volume (inches) for time interval						
		1 hour	2 hours	6 hours	12 hours	1 day	2 days	8 days
1965	0.002	0.002	0.005	0.014	0.028	0.053	0.091	0.195
1966	.034	.034	.068	.165	.362	.775	1.37	2.94
1967	.032	.032	.064	.192	.380	.727	1.32	2.96
1968	.034	.034	.068	.204	.404	.780	1.44	4.94
1969	.036	.036	.072	.212	.419	.810	1.55	4.02
1970	.039	.039	.078	.236	.471	.880	1.66	3.18
1971	.028	.028	.056	.167	.333	.648	1.21	2.43
1972	.016	.016	.032	.094	.186	.360	.568	1.19
1973	.017	.017	.032	.095	.177	.323	.514	.961
1974	.059	.058	.113	.303	.536	.751	1.26	3.39
1975	.009	.009	.019	.055	.105	.203	.366	.928
Maximum 1965–1975. . . .	0.059	0.058	0.113	0.303	0.536	0.880	1.66	4.94

Table A-17.—Monthly maximum mean daily discharge, in cubic feet per second, for watershed W-2

Year	Month												Annual maximum
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1955	......	......	......	......	......	......	......	......	......	86.0	6.1	7.2	....
1956	6.7	2.0	0.8	0.7	187.0	64.0	83.0	4.6	396.0	6,070.0	107.0	4.4	6,070.0
1957	10.0	46.0	131.0	165.0	354.0	272.0	381.0	860.0	905.0	328.0	17.0	109.0	905.0
1958	780.0	235.0	715.0	104.0	26.0	99.0	510.0	427.0	252.0	73.0	24.0	31.0	780.0
1959	170.0	110.0	1,300.0	106.0	75.0	4,250.0	190.0	108.0	525.0	1,190.0	425.0	62.0	4,250.0
1960	49.0	971.0	1,810.0	72.0	14.0	742.0	875.0	935.0	2,330.0	1,310.0	80.0	4.8	2,330.0
1961	36.0	6.6	2.4	1.4	2.0	16.0	14.0	35.0	34.0	3.5	4.5	2.4	35.0
1962	2.0	2.4	12.0	27.0	19.0	394.0	1,280.0	872.0	1,100.0	170.0	28.0	9.3	1,280.0
1963	10.0	200.0	130.0	3.4	3.7	22.0	18.0	5.8	150.0	140.0	21.0	25.0	200.0
1964	78.0	240.0	14.0	31.0	61.0	32.0	54.0	2,210.0	1,020.0	53.0	11.0	37.0	2,210.0
1965	8.0	47.0	61.0	14.0	4.7	117.0	194.0	108.0	30.0	96.0	98.0	11.0	194.0
1966	215.0	512.0	59.0	52.0	140.0	410.0	800.0	1,450.0	231.0	1,280.0	24.0	16.0	1,450.0
1967	12.0	50.0	17.0	8.5	2.3	217.0	975.0	1,180.0	1,260.0	533.0	34.0	23.0	1,260.0
1968	17.0	18.0	12.0	4.4	67.0	1,800.0	1,890.0	172.0	379.0	898.0	436.0	24.0	1,890.0
1969	87.0	30.0	2,290.0	68.0	565.0	2,360.0	253.0	1,390.0	624.0	2,240.0	1,560.0	794.0	2,360.0
1970	1,170.0	778.0	2,280.0	141.0	373.0	329.0	770.0	400.0	153.0	451.0	62.0	16.0	2,280.0
1971	18.0	94.0	21.0	7.9	83.0	906.0	1,060.0	531.0	940.0	284.0	158.0	26.0	1,060.0
1972	22.0	25.0	161.0	329.0	83.0	817.0	74.0	1,190.0	1,090.0	40.0	20.0	24.0	1,190.0
1973	86.0	93.0	85.0	29.0	43.0	278.0	520.0	340.0	347.0	528.0	168.0	39.0	528.0
1974	39.0	47.0	24.0	45.0	30.0	480.0	1,370.0	974.0	265.0	657.0	31.0	36.0	1,370.0
1975	48.0	34.0	17.0	31.0	19.0	70.0	150.0	106.0	320.0	230.0	117.0	30.0	320.0
Maximum, 1955–75	1,170.0	971.0	2,290.0	329.0	565.0	4,250.0	1,890.0	2,210.0	2,330.0	6,070.0	1,560.0	794.0	6,070.0

Table A-18.—Monthly maximum mean daily discharge, in cubic feet per second, for subwatershed W-3

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual maximum
1955	......	......	......	......	......	60.0	233.0	258.0	37.0	38.0	0.4	0.6	....
1956	1.3	1.3	0.5	44.0	84.0	2.5	3.5	9.2	229.0	1,370.0	3.7	.8	1,370.0
1957	4.1	5.1	62.0	121.0	45.0	90.0	81.0	237.0	457.0	87.0	.5	16.0	457.0
1958	235.0	14.0	222.0	42.0	12.0	15.0	105.0	45.0	44.0	52.0	2.4	5.6	235.0
1959	61.0	5.6	392.0	7.1	57.0	714.0	4.5	27.0	20.0	466.0	39.0	45.0	714.0
1960	4.5	85.0	647.0	3.4	.9	280.0	230.0	97.0	381.0	64.0	6.2	.6	647.0
1961	4.4	.8	1.3	1.3	1.4	21.0	2.6	1.6	1.5	1.6	.2	.1	21.0
1962	.1	0	8.5	3.2	36.0	154.0	198.0	212.0	248.0	67.0	11.0	.6	248.0
1963	.4	16.0	7.0	.2	1.3	9.7	7.4	1.2	105.0	13.0	9.3	17.0	105.0
1964	21.0	120.0	3.3	4.0	8.0	5.0	4.2	468.0	245.0	8.0	1.9	11.0	468.0
1965	1.6	4.7	13.0	1.4	.2	3.0	50.0	100.0	25.0	18.0	14.0	4.3	100.0
1966	28.0	80.0	11.0	2.4	.3	40.0	100.0	150.0	22.0	150.0	3.6	.76	150.0
1967	.44	3.8	1.4	.14	0	100.0	500.0	160.0	91.0	36.0	10.0	4.6	500.0
1968	2.6	1.6	1.0	.18	3.4	268.0	751.0	63.0	17.0	92.0	90.0	4.1	751.0
1969	9.7	3.6	312.0	15.0	66.0	600.0	18.0	338.0	19.0	684.0	212.0	52.0	684.0
1970	150.0	89.0	541.0	26.0	57.0	82.0	63.0	21.0	43.0	72.0	3.6	1.8	541.0
1971	1.8	38.0	3.8	1.6	6.6	186.0	116.0	106.0	291.0	121.0	19.0	7.9	291.0
1972	7.2	6.6	16.0	12.0	17.0	160.0	8.1	386.0	226.0	5.9	7.0	6.8	386.0
1973	14.0	32.0	43.0	8.2	17.0	21.0	322.0	188.0	179.0	37.0	61.0	24.0	322.0
1974	3.4	2.8	.9	5.1	.23	116.0	715.0	272.0	186.0	109.0	.6	1.6	715.0
1975	1.4	3.8	.7	.16	0	30.0	54.0	35.0	40.0	108.0	53.0	2.6	108.0
Maximum, 1955-75	235.0	120.0	647.0	121.0	84.0	714.0	751.0	468.0	457.0	1,370.0	212.0	52.0	1,370.0

Table A-19.—Monthly maximum mean daily discharge, in cubic feet per second, for subwatershed W-5

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual maximum
1964	....	....	....	16	20	26	44	932	365	37	5.8	18	932
1965	4.2	34	41	7.8	2.8	61	44	11	13	51	34	5.2	61
1966	117	212	30	40	134	222	428	720	175	435	10	6.8	720
1967	6.2	21	5.8	3.4	2.2	17	693	365	212	273	6.5	7.7	693
1968	7.3	7.3	4.2	3.6	19	747	543	62	304	539	108	6.5	747
1969	27	10	608	13	260	770	175	515	495	613	437	475	770
1970	431	282	835	61	85	138	478	386	102	210	48	5.0	835
1971	5.0	8.6	8.6	3.9	37	212	293	146	618	26	110	10	618
1972	5.7	12	110	220	7.0	307	16	343	272	6.9	6.9	11	343
1973	36	29	17	9.1	23	188	150	230	98	307	12	6.1	307
1974	5.0	3.9	3.9	3.3	2.1	140	715	301	82	128	5.0	7.7	715
1975	5.0	19.0	3.6	3.3	6.9	119	79	25	193	76	8.1	6.9	193
Maximum, 1964-75	431	282	835	220	260	770	693	932	618	613	437	475	932

Table A-20.—Mean monthly ground-water levels below ground surface, in feet, for watershed W-2

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	....	....	1.21	2.01	2.80	1.38	1.67	1.83	1.35	1.22	1.30	1.93
1960	2.40	1.23	1.61	2.32	3.03	1.96	1.43	1.14	.43	1.42	2.35	3.06
1961	2.90	3.02	3.51	3.87	4.34	3.16	3.08	3.34	3.25	3.80	4.02	4.61
1962	4.90	5.16	5.21	4.01	3.68	2.49	1.17	.89	.76	2.22	2.55	3.12
1963	3.46	3.05	2.57	3.94	4.10	3.26	3.38	4.10	3.38	3.02	3.26	3.19
1964	1.88	1.63	2.68	3.43	3.14	3.62	3.24	2.54	.85	1.82	2.80	2.89
1965	3.48	3.56	2.98	3.69	4.55	3.94	2.81	1.83	2.52	2.03	2.56	3.41
1966	1.82	1.70	2.39	3.13	3.79	1.91	.80	.44	1.76	1.58	2.60	3.52
1967	3.90	3.67	3.52	4.46	5.19	3.16	.91	1.10	1.40	1.49	2.75	3.21
1968	3.45	3.73	3.80	4.57	4.68	.72	.68	1.88	1.92	1.68	1.75	2.82
1969	2.41	2.93	1.56	2.17	1.78	1.67	2.11	.86	1.70	.87	1.01	1.51
1970	1.08	1.62	1.33	2.66	3.81	2.01	1.64	2.16	2.43	1.65	3.12	3.92
1971	4.33	4.21	3.77	4.38	4.20	2.15	1.18	1.15	1.12	1.64	2.47	3.03
1972	3.58	3.51	4.01	3.64	4.14	2.77	2.84	3.22	2.28	3.66	3.88	3.50
1973	2.92	2.16	2.71	3.07	3.45	2.51	.99	1.02	1.29	1.86	2.67	3.29
1974	3.37	3.74	4.33	4.38	4.88	3.80	.84	.88	2.13	2.23	3.63	3.58
1975	3.94	4.02	4.49	5.04	[1]5.37	4.66	2.70	2.86	2.01	2.62	3.07	3.77
Average	3.11	3.06	3.04	3.57	3.94	2.66	1.85	1.84	1.80	2.05	2.69	3.20

[1]Estimate.

Table A-21.—Mean monthly ground-water levels below ground surface, in feet, for subwatershed W-3

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	[1]1.75	[1]1.61	0.94	1.95	2.60	1.28	[2]2.43	1.80	1.52	0.90	1.12	1.42
1960	1.74	.86	1.05	2.04	2.68	1.51	.70	.84	.25	.81	1.72	2.50
1961	2.41	2.34	2.75	2.82	3.47	2.63	2.47	2.64	2.37	3.29	3.96	4.33
1962	4.45	4.62	4.67	3.87	3.34	2.66	.97	.64	.41	1.75	1.79	2.31
1963	2.63	2.23	1.94	3.31	3.45	2.25	1.98	3.06	2.61	1.71	1.69	1.84
1964	.82	.87	1.88	2.67	2.30	2.78	2.46	2.54	.60	1.12	2.06	1.76
1965	2.28	2.41	2.03	3.05	3.98	3.75	2.36	1.07	1.74	1.24	2.14	2.91
1966	1.38	1.24	2.21	3.05	3.75	1.93	.82	.55	1.95	1.47	2.79	3.19
1967	3.55	3.78	3.26	4.08	4.66	2.50	.78	1.07	1.06	1.23	2.20	2.60
1968	2.81	3.11	3.21	3.87	3.90	.63	.58	1.10	1.67	1.47	1.41	2.57
1969	2.03	2.53	1.35	1.85	1.78	1.85	2.03	.76	1.59	.75	.79	1.19
1970	.79	1.23	1.00	2.41	3.48	1.55	1.27	1.99	1.69	1.22	2.87	3.57
1971	3.94	3.74	3.05	4.39	3.92	1.71	.90	.63	.79	1.04	1.94	2.40
1972	3.18	2.96	3.47	3.34	3.82	2.39	2.17	2.82	1.72	3.04	3.06	2.76
1973	2.02	1.33	1.80	2.44	3.01	2.30	.69	.72	.76	1.57	2.15	2.68
1974	2.75	3.07	3.79	3.69	4.31	3.56	.54	.56	1.31	1.85	3.36	3.15
1975	3.38	3.65	4.10	4.60	5.09	4.50	2.25	2.14	1.47	1.28	1.89	2.76
Average	2.47	2.45	2.50	3.14	3.50	2.34	1.49	1.47	1.38	1.51	2.17	2.58

[1]Ground-water well 1.
[2]Ground-water well 2.

Table A-22.—Mean monthly ground-water levels below ground surface, in feet, for subwatershed W-5

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	1.58	1.42	2.58	3.45	2.99	3.42	3.02	2.32	0.46	1.80	2.68	2.95
1965	3.60	3.55	2.82	3.47	4.65	3.84	3.02	2.54	3.24	2.28	2.62	3.52
1966	1.93	1.84	2.21	2.76	3.06	1.22	.22	.04	1.08	1.10	2.38	3.25
1967	3.62	3.64	3.54	4.53	5.36	3.66	.46	.92	1.32	1.27	1.68	3.16
1968	3.25	3.42	3.24	4.28	4.77	.55	.71	2.12	1.18	[1].20	.51	1.50
1969	1.36	1.87	.71	1.54	1.38	.38	.79	.28	.29	.28	.60	.84
1970	.95	1.28	1.04	2.12	3.46	1.30	1.15	1.08	2.10	1.18	1.95	3.11
1971	3.50	3.30	3.57	4.14	3.89	2.08	1.48	1.98	1.51	1.95	2.13	2.54
1972	2.66	2.37	3.10	2.40	3.45	2.57	3.07	3.83	2.60	3.68	3.91	3.63
1973	3.26	2.62	2.85	3.30	3.33	2.18	1.21	1.57	1.36	[2]1.86	2.94	3.55
1974	3.64	4.04	4.39	4.71	5.02	3.32	1.05	.96	2.28	2.08	3.48	3.55
1975	3.93	[3]4.07	[3]4.23	[3]4.83	[3]5.01	[3]3.84	2.35	3.07	2.34	2.57	3.48	4.03
Average	2.77	2.78	2.86	3.46	3.86	2.36	1.54	1.73	1.65	1.69	2.36	2.97

[1]Begin 1 well.
[2]Begin 2 wells.
[3]Estimate.

Table A-23.—Mean monthly depth to ground water, in feet, for observation wells and recorder wells

Month	Observation wells 1	2	3	4	5	6[1]	7	Recorder well A[2]	Recorder well B[3]
1959									
January	1.75	....	....	2.70	....	....	....	....	....
February	1.61	....	....	2.52	....	....	....	....	....
March	.97	0.90	1.17	1.63	1.45	1.31	1.06	....	....
April	1.79	2.11	1.52	2.09	2.08	2.70	1.78	....	....
May	2.31	2.88	3.28	2.42	3.20	3.43	2.13	....	....
June	1.25	1.31	2.14	1.25	1.10	1.50	1.11	....	....
July	....	2.43	2.15	2.08	1.42	.94	.97	....	....
August	1.66	1.93	2.28	2.49	1.71	1.60	1.11	....	....
September	1.77	1.36	2.69	1.51	.48	1.08	.59	....	....
October	1.03	.76	2.01	1.32	.93	1.25	.89	....	....
November	1.30	.93	1.97	1.89	1.19	.90	.93	....	....
December	1.41	1.45	2.59	2.49	2.02	2.24	1.34	....	....
1960									
January	1.86	1.56	3.07	3.01	2.67	2.82	1.79	....	....
February	1.01	.78	1.74	1.83	.82	1.30	1.11	....	....
March	1.31	.78	2.19	1.98	2.00	1.84	1.19	....	....
April	1.93	2.08	2.84	2.65	2.57	2.46	1.68	....	....
May	2.91	2.44	3.59	3.70	2.96	3.45	2.18	....	....
June	1.34	1.68	2.89	2.35	2.08	2.16	1.24	....	....
July	1.17	.45	1.91	1.74	1.17	1.92	1.63	....	....
August	.82	.81	1.27	1.34	.72	1.45	1.22	....	....
September	.32	.20	1.11	.48	.08	.61	....	....	....
October	1.01	.61	1.87	2.07	1.41	1.68	....	....	....
November	1.84	1.76	2.92	2.89	2.74	2.67	1.63	....	....
December	2.28	2.72	3.82	3.71	3.63	3.57	2.01	....	....
1961									
January	2.22	2.53	3.66	3.56	3.37	3.28	1.68	....	....
February	2.26	2.43	3.79	3.64	3.58	3.56	1.86	....	....
March	2.97	2.52	4.38	4.05	4.35	3.97	2.32	....	....
April	3.19	2.45	4.80	4.32	4.70	4.55	3.05	....	....
May	3.94	3.00	5.20	4.77	5.06	4.94	3.46	....	....
June	3.17	2.00	3.55	3.95	4.24	3.28	1.86	....	....
July	3.18	1.70	3.94	3.42	4.94	2.92	1.49	....	....
August	2.97	2.32	4.59	4.05	4.89	3.21	1.38	....	....
September	2.80	1.95	4.86	4.21	4.30	3.15	1.49	....	....
October	3.79	2.80	5.18	4.36	4.82	3.83	1.81	....	....
November	4.12	3.80	5.12	4.30	4.81	3.78	2.22	....	....
December	4.43	4.24	5.48	4.76	5.42	4.42	3.51	....	....
1962									
January	4.50	4.40	5.81	5.16	5.62	4.88	3.90	....	....
February	4.80	4.51	6.01	5.40	5.84	5.22	4.37	....	....
March	4.80	4.53	5.95	5.44	5.92	5.31	4.50	....	....
April	4.00	3.75	3.76	4.22	5.05	4.18	3.13	....	....
May	3.82	2.88	3.53	4.02	4.57	3.99	2.93	....	....
June	2.96	2.36	2.72	2.98	2.98	2.15	1.26	....	....
July	1.19	.67	1.78	1.33	.97	1.44	.84	....	....
August	.39	.85	1.40	.72	.35	1.70	.84	....	....
September	.48	.33	1.45	1.33	.47	.83	.43	....	....
October	1.82	1.68	2.58	2.97	2.25	2.69	1.58	2.20	1.95
November	1.74	1.84	3.18	3.42	2.94	3.02	1.72	2.92	2.18
December	2.07	2.54	3.83	3.93	3.58	3.60	2.31	2.63	2.37

See footnotes at end of table.

Table A-23.—Mean monthly depth to ground water, in feet, for observation wells and recorder wells—Continued

Month	Observation wells 1	2	3	4	5	[1]6	7	Recorder well A[2]	Recorder well B[3]
					1963				
January	2.31	2.93	4.08	4.19	3.88	3.82	3.00	2.76	2.11
February	1.95	2.51	3.88	3.96	3.53	3.41	2.14	2.41	1.34
March	2.09	1.79	3.19	3.19	3.10	2.90	1.74	2.44	2.09
April	3.34	3.28	4.73	4.19	4.28	4.35	3.44	3.62	3.67
May	3.52	3.37	5.06	4.04	4.18	4.89	3.63	3.52	3.55
June	2.38	2.12	3.91	2.67	3.24	4.47	4.05	2.04	3.20
July	1.96	2.01	4.11	3.01	3.09	4.99	4.46	2.64	2.94
August	3.01	3.11	5.27	3.86	3.79	5.33	4.35	3.43	3.06
September	2.74	2.48	4.69	3.26	3.95	4.17	2.37	2.67	1.96
October	1.37	2.04	4.44	3.16	3.99	3.96	2.17	2.60	2.05
November	1.34	2.03	4.57	3.38	4.14	3.98	2.41	2.59	2.06
December	1.41	2.26	4.61	3.64	4.26	3.91	2.26	2.51	1.65
					1964				
January	0.81	0.84	3.10	2.42	2.83	2.19	0.97	1.61	0.54
February	.88	.86	2.51	2.12	2.19	1.92	.92	1.47	1.76
March	1.70	2.06	3.48	3.09	3.27	3.03	2.13	2.72	2.49
April	2.26	3.08	3.92	3.81	4.02	3.88	3.02	3.17	4.76
May	1.80	2.81	3.76	3.60	4.00	3.76	2.22	2.77	5.32
June	2.17	3.40	4.64	4.36	3.95	4.60	2.23	3.10	5.25
July	1.94	2.99	4.77	4.21	2.71	4.24	1.81	.84	6.10
August	.88	2.24	4.44	3.65	1.94	3.69	.95	.74	5.09
September	.67	.52	1.79	1.38	.67	.92	.01	1.17	.77
October	1.12	1.12	2.08	2.49	2.34	2.65	.95	2.11	1.55
November	1.75	2.36	3.34	3.38	3.43	3.68	1.67	2.91	3.68
December	1.66	1.86	3.21	3.83	3.75	4.24	1.66	2.68	3.85
					1965				
January	2.03	2.53	3.98	4.28	4.37	4.68	2.52	2.91	4.05
February	1.87	2.94	4.21	4.39	4.44	4.76	2.33	3.12	3.57
March	1.85	2.21	3.84	3.76	3.57	4.23	1.40	2.59	3.06
April	3.05	3.05	4.53	4.40	3.84	4.61	2.33	3.44	3.29
May	4.01	3.86	5.11	4.89	4.65	5.51	3.79	4.20	4.28
June	3.84	3.67	3.99	4.84	3.54	4.60	3.09	3.67	2.75
July	2.51	2.21	2.62	4.15	2.17	3.82	2.21	2.64	1.97
August	1.41	.73	1.94	2.24	1.40	3.41	1.68	1.69	1.57
September	2.48	1.00	2.11	2.54	3.02	4.25	2.24	1.93	2.78
October	1.61	.93	1.86	2.17	3.13	3.55	1.00	2.12	2.32
November	2.51	1.78	2.67	2.57	3.18	3.82	1.42	1.38	2.96
December	3.12	2.70	3.54	3.38	4.08	4.73	2.32	1.09	3.71
					1966				
January	1.09	1.06	1.80	1.83	2.57	2.88	0.98	0.38	1.36
February	1.65	.82	1.94	1.84	2.00	2.60	1.07	.57	1.54
March	2.64	1.78	2.88	2.62	2.42	3.02	1.40	1.62	2.64
April	3.37	2.74	3.68	3.42	3.20	3.83	1.69	2.12	3.07
May	3.82	3.68	4.68	4.08	4.14	4.55	1.56	3.20	3.49
June	2.46	1.40	2.73	2.91	1.41	2.10	.35	1.49	1.37
July	1.24	.41	1.51	1.33	.67	.78	−.33	1.15	.65
August	.82	.28	1.03	1.09	−.20	.43	−.35	.71	2.87
September	2.57	.92	2.96	2.79	2.25	1.45	.72	2.07	2.28
October	1.64	1.31	2.22	2.33	1.28	1.35	.86	1.70	1.22
November	2.38	2.53	3.37	3.22	2.99	3.10	1.66	2.66	3.23
December	3.15	3.23	4.07	4.01	3.71	4.07	2.43	3.02	2.69

See footnotes at end of table.

Table A-23.—Mean monthly depth to ground water, in feet, for observation wells and recorder wells—Continued

Month	Observation wells 1	2	3	4	5	[1]6	7	Recorder well A[2]	Recorder well B[3]
					1967				
January	3.49	3.61	4.40	4.45	4.06	4.56	2.69	3.19	3.81
February	3.18	3.37	3.96	4.37	3.52	4.60	2.68	2.74	3.66
March	3.34	3.18	3.81	4.07	3.17	4.31	2.78	3.10	3.59
April	4.20	3.96	4.98	4.81	4.17	5.22	3.84	4.00	4.49
May	4.78	4.54	5.89	5.41	4.97	6.01	4.72	4.77	5.25
June	3.11	1.88	3.06	2.89	3.87	4.76	2.57	1.92	4.16
July	1.17	.39	1.54	1.04	1.32	1.08	−.16	.94	1.74
August	1.79	.42	1.42	1.40	.65	1.06	.77	.88	.78
September	1.56	.57	1.86	1.35	1.80	1.94	.69	1.48	1.37
October	1.39	1.07	2.18	1.64	1.65	1.63	.91	2.02	1.75
November	2.33	2.08	3.36	2.85	3.36	3.26	2.11	2.55	3.44
December	2.44	2.77	3.78	3.44	3.69	3.86	2.47	2.51	3.50
					1968				
January	2.59	3.03	4.12	4.85	4.09	4.21	2.27	2.69	3.47
February	2.68	3.55	4.44	4.27	4.34	4.47	2.37	2.73	3.63
March	2.83	3.59	4.70	4.45	4.58	4.63	1.85	2.94	3.62
April	3.61	4.13	5.52	5.09	5.10	5.26	3.31	3.36	4.40
May	3.48	4.32	5.30	5.05	5.08	5.57	3.97	4.14	4.26
June	.63	.63	1.39	.78	.54	1.22	−.12	.98	.38
July	.76	.31	1.13	.56	.60	1.28	.14	.89	.76
August	1.28	.92	2.33	2.38	1.89	2.86	1.48	2.10	1.93
September	1.89	1.46	2.45	2.71	2.57	1.52	.85	2.47	1.21
October	1.77	1.18	2.22	3.17	1.51	....	.20	2.01	1.21
November	1.68	1.13	2.35	3.06	1.77	....	.51	1.91	1.76
December	2.65	2.50	3.49	3.72	3.09	....	1.50	2.79	3.06
					1969				
January	2.16	1.90	2.98	3.21	2.87	....	1.36	2.49	2.69
February	2.63	2.43	3.56	3.71	3.40	....	1.87	2.90	3.22
March	1.64	1.06	2.19	2.24	1.51	....	.71	1.57	1.30
April	2.66	1.04	2.87	2.47	2.45	....	1.54	2.23	2.94
May	2.60	.96	2.69	1.76	1.31	....	1.38	1.77	1.29
June	2.30	1.40	2.46	1.92	1.54	....	.38	1.68	1.61
July	2.14	1.91	3.03	2.72	2.08	....	.79	2.51	2.31
August	.88	.65	1.61	1.22	.81	....	.28	1.14	.74
September	2.08	1.11	2.33	2.38	2.14	....	.29	1.54	.92
October	.98	.52	1.58	.92	.92	....	.28	1.22	.75
November	.91	.66	1.75	1.16	1.01	....	.60	1.57	.98
December	1.11	1.26	2.26	2.07	1.49	....	.84	.98	1.30
					1970				
January	0.67	0.88	1.77	1.47	0.77	....	0.95	1.35	0.77
February	1.05	.53	2.29	2.05	1.52	....	1.28	1.99	1.40
March	.79	1.20	2.02	1.92	.97	....	1.04	2.48	1.04
April	2.50	2.32	3.38	3.00	2.71	....	2.12	3.00	2.86
May	3.41	3.54	4.52	3.98	3.95	....	3.46	3.64	3.76
June	1.92	1.19	2.64	2.38	2.63	....	1.30	2.33	1.75
July	.75	1.78	2.13	1.76	2.24	....	1.15	2.60	.60
August	1.93	2.06	2.71	2.89	2.27	....	1.08	2.35	2.22
September	1.52	1.86	2.79	3.64	2.77	....	2.10	2.59	2.83
October	1.01	1.43	2.25	2.79	1.32	....	1.18	2.25	1.19
November	2.66	3.07	3.87	3.79	3.39	....	1.95	3.27	3.33
December	3.31	3.81	4.60	4.48	4.19	....	3.11	3.51	3.87

See footnotes at end of table.

Table A-23.—Mean monthly depth to ground water, in feet, for observation wells and recorder wells—Continued

Month	Observation wells 1	2	3	4	5	[1]6	7	Recorder well A[2]	Recorder well B[3]
					1971				
January	3.61	4.26	5.01	4.99	4.61	....	3.50	3.62	4.10
February	3.32	4.16	4.99	4.63	4.84	....	3.30	3.11	4.06
March	2.67	3.42	4.28	3.61	5.07	....	3.57	2.97	4.30
April	3.39	4.05	5.06	4.29	5.35	....	4.14	3.63	4.63
May	3.71	4.12	5.02	4.14	5.05	....	3.89	3.63	4.21
June	1.78	1.64	2.51	2.43	2.43	....	2.08	2.06	1.74
July	.99	.82	1.21	1.47	1.11	....	1.48	2.11	1.39
August	.46	.74	1.75	.78	1.18	....	1.98	2.06	1.29
September	.76	.81	1.61	1.05	1.06	....	1.51	1.82	.88
October	1.11	.98	1.99	2.11	1.68	....	1.95	....	....
November	1.56	2.31	3.35	3.00	2.49	....	2.43	....	....
December	2.09	2.77	3.95	3.53	3.29	....	2.54	....	....
					1972				
January	2.89	3.47	4.38	4.11	4.00	....	2.66	....	....
February	2.55	3.37	4.65	4.26	3.86	....	2.37	....	....
March	3.31	3.64	5.10	4.52	4.37	....	3.10	....	3.59
April	3.15	3.52	4.71	4.28	3.79	....	2.40	....	2.74
May	3.68	3.96	5.02	4.41	4.30	....	3.45	....	4.05
June	2.36	2.41	3.36	3.15	2.79	....	2.57	....	3.14
July	2.54	1.80	3.53	2.83	3.25	....	3.07	....	2.32
August	3.05	2.56	3.65	2.84	3.38	....	3.83	....	[4]3.40
September	1.70	1.75	3.21	2.01	2.44	....	2.60	....	2.19
October	2.74	3.33	4.50	3.62	4.06	....	3.68	....	3.46
November	2.86	3.26	4.85	3.91	4.49	....	4.91	....	3.66
December	2.57	2.94	4.22	3.89	3.67	....	3.74	....	3.68
					1973				
January	1.70	2.35	3.68	3.47	3.05	....	3.39	....	3.45
February	1.09	1.58	2.81	2.56	2.26	....	2.62	....	2.46
March	1.30	2.30	3.69	2.78	3.23	....	2.95	....	3.44
April	2.16	2.72	3.79	3.20	3.08	....	3.30	....	3.75
May	2.64	3.38	4.67	3.81	2.91	....	3.33	....	4.13
June	1.36	3.23	3.85	3.01	1.42	....	2.19	....	[4]2.87
July	.39	.98	1.79	1.07	.48	....	1.21	....	....
August	.64	.79	1.28	.73	1.10	....	1.57	....	[4].93
September	.66	.85	2.15	1.18	1.49	....	1.36	....	1.30
October	.75	2.40	2.91	1.42	1.82	2.37	1.35	....	1.88
November	1.59	2.64	3.21	2.29	3.00	3.28	2.60	....	3.15
December	2.03	3.32	3.97	3.15	3.52	4.09	3.01	....	3.56
					1974				
January	2.10	3.40	3.79	3.32	3.66	4.25	3.14	....	3.64
February	2.45	3.68	4.01	3.89	3.83	4.69	3.38	....	4.15
March	3.31	4.27	4.80	4.43	4.72	5.05	3.72	....	4.59
April	3.09	4.29	4.68	4.36	4.80	5.22	3.90	....	4.71
May	3.92	4.69	5.49	5.15	4.90	5.77	4.27	....	5.07
June	3.35	3.76	3.96	4.78	4.07	4.40	2.25	....	[4]3.75
July	.29	.79	1.09	.76	.85	1.09	1.01	....	.50
August	.30	.81	1.49	.46	1.03	.77	1.15	....	.92
September	1.12	1.49	2.51	2.24	2.96	2.06	2.51	....	3.12
October	1.58	2.12	2.48	2.44	2.79	2.01	2.15	....	2.81
November	3.20	3.52	4.02	3.54	4.15	3.60	3.35	....	3.94
December	2.75	3.55	4.04	3.67	3.94	3.83	3.26	....	3.92

See footnotes at end of table.

Table A-23.—Mean monthly depth to ground water, in feet, for observation wells and recorder wells—Continued

Month	Observation wells 1	2	3	4	5	[1]6	7	Recorder well A[2]	Recorder well B[3]
					1975				
January	2.94	3.82	4.46	4.09	4.39	4.26	3.60	....	4.08
February	3.30	3.99	4.40	4.30	4.58	[4]4.58	3.56	....	4.26
March	3.82	4.38	5.17	4.78	4.85	[4]4.75	3.71	....	4.48
April	4.27	4.93	[4]5.87	5.20	5.36	[4]5.20	4.46	....	5.09
May	4.73	5.44	[4]6.15	5.81	5.82	[4]5.60	4.41	....	5.42
June	4.56	4.44	[4]5.36	5.35	5.26	[4]4.53	3.15	....	4.62
July	1.42	3.08	3.59	3.66	2.47	2.98	1.71	....	[4]1.47
August	1.37	2.91	4.12	3.48	2.04	3.63	2.50	....	2.34
September	1.35	1.59	3.01	2.79	.64	3.00	1.69	....	1.96
October	.95	1.62	2.99	3.08	1.96	2.54	2.60	....	[4]2.63
November	1.59	2.18	3.83	3.83	3.10	3.65	3.30	....	3.50
December	2.43	3.08	4.64	4.40	3.79	[4]4.20	3.86	....	3.98
				Averages for each month, 1959–75					
January	2.22	2.66	3.76	3.59	3.55	3.80	2.40	2.33	2.84
February	2.25	2.59	3.70	3.51	3.41	3.74	2.33	2.34	2.92
March	2.39	2.57	3.70	3.44	3.44	3.70	2.30	2.49	3.09
April	3.04	3.15	4.16	3.87	3.91	4.29	2.89	3.17	3.88
May	3.43	3.52	4.64	4.18	4.18	4.79	3.22	3.52	4.16
June	2.45	2.27	3.24	3.06	2.77	3.31	1.86	2.14	2.81
July	1.48	1.45	2.46	2.18	1.86	2.29	1.38	1.81	1.90
August	1.39	1.42	2.50	2.10	1.70	2.01	1.52	1.68	2.09
September	1.56	1.19	2.56	2.17	1.95	2.08	1.34	1.97	1.81
October	1.43	1.52	2.67	2.47	2.23	2.46	1.47	2.03	1.91
November	2.08	2.24	3.40	3.09	3.07	3.23	2.08	2.42	2.86
December	2.41	2.76	3.89	3.42	3.60	3.90	2.48	2.41	3.11

[1]Recorder inactive October 1968 to September 1973; site moved from road right-of-way.
[2]Operation terminated September 1971.
[3]Not operated October 1971 through February 1972; recorder relocated.
[4]Estimated.

Table A-24.—Mean monthly ground-water elevations, in feet, for 104- and 535-foot well locations on lines A and B and 2,000-foot location on line B

Month	Line A wells (ft)		Line B wells (ft)		
	104	[1]535	[2]104	535	2,000
			1962		
January	36.08	37.68	22.57	22.54	26.86
February	35.88	37.53	22.17	22.00	26.55
March	35.71	37.37	22.22	22.04	26.28
April	36.60	38.09	22.87	22.97	27.49
May	36.91	38.87	22.58	22.71	27.50
June	37.46	39.65	24.85	25.35	29.46
July	39.09	41.41	25.71	25.69	30.95
August	38.94	41.68	25.39	25.52	30.93
September	39.26	41.62	26.46	26.60	31.56
October	37.66	39.97	24.00	24.10	30.10
November	37.77	40.05	23.55	23.69	29.65
December	37.27	39.62	23.41	23.43	28.99
			1963		
January	37.01	39.18	24.30	24.21	28.66
February	37.12	39.17	24.17	24.42	28.89
March	37.50	39.61	23.58	23.93	29.75
April	36.34	38.51	22.16	22.23	28.45
May	36.51	38.73	22.29	22.32	27.84
June	37.54	39.80	22.66	22.48	27.28
July	37.14	39.36	23.06	22.87	27.72
August	36.47	38.67	22.65	22.66	27.23
September	37.16	39.21	23.60	23.94	28.90
October	37.19	39.18	23.77	24.09	29.38
November	37.42	39.30	23.64	24.02	29.24
December	37.38	39.16	23.93	24.31	29.16
			1964		
January	38.38	40.45	24.78	25.36	30.37
February	38.74	40.97	24.71	25.22	30.94
March	37.18	39.79	20.62	23.19	29.62
April	36.82	38.93	....	21.25	28.77
May	37.00	39.24	....	20.59	28.46
June	36.58	38.72	....	20.53	28.68
July	38.76	40.28	....	19.81	27.89
August	39.03	41.55	....	20.24	28.06
September	38.83	41.06	....	25.34	31.20
October	37.82	40.38	....	24.06	30.66
November	37.02	39.45	....	22.26	29.80
December	37.41	39.54	....	22.14	29.31
			1965		
January	37.08	39.08	....	21.99	28.73
February	36.81	38.91	....	21.96	29.10
March	37.22	39.30	....	22.76	29.64
April	36.50	38.83	....	22.61	29.07
May	35.73	38.22	....	21.63	27.93
June	36.34	38.47	....	23.38	28.97
July	37.39	39.55	....	22.13	30.10
August	38.21	40.62	....	23.95	30.76
September	37.58	40.00	....	23.93	30.85
October	37.77	40.20	....	23.80	30.76
November	38.30	39.82	....	22.97	30.07
December	38.49	39.35	....	22.16	29.11
			1966		
January	39.45	40.76	....	24.11	29.86
February	29.43	40.96	....	24.49	30.48
March	38.33	39.84	....	23.25	29.98
April	37.69	39.15	....	22.85	29.65
May	36.62	38.26	....	22.38	29.04
June	38.65	40.72	....	24.43	30.77
July	38.97	41.13	....	24.84	31.65
August	39.12	41.49	....	25.25	32.08
September	37.87	40.03	....	23.32	30.29
October	38.04	40.07	....	24.65	30.84
November	37.02	39.26	....	22.70	29.71
December	36.75	38.59	....	22.22	28.92
			1967		
January	36.56	38.24	....	22.09	28.39
February	37.08	38.58	....	22.30	28.06
March	36.78	38.61	....	22.28	28.36
April	35.84	37.89	....	21.40	27.52
May	35.09	37.26	....	20.63	26.68
June	38.79	40.76	....	21.51	27.39
July	39.26	41.11	....	24.80	30.11
August	38.95	41.13	....	25.08	30.71
September	38.61	40.68	....	24.45	30.66
October	38.16	40.56	....	24.40	30.88
November	37.30	39.43	....	22.42	29.41
December	37.30	39.06	....	22.37	28.90
			1968		
January	37.06	38.62	....	22.37	28.67
February	37.02	38.39	....	22.34	28.34
March	36.84	38.39	....	22.19	28.18
April	36.05	37.66	....	21.50	27.56
May	35.66	37.46	....	21.32	27.30
June	39.30	41.69	....	25.80	31.87
July	39.36	41.49	....	25.13	31.86
August	37.74	39.92	....	23.67	29.18
September	37.12	39.47	....	24.74	30.72
October	37.88	40.40	....	24.71	30.56
November	38.11	40.45	....	24.14	30.46
December	37.11	39.19	....	22.89	29.23

See footnotes at end of table.

Table A-24.—Mean monthly ground-water elevations, in feet, for 104- and 535-foot well locations on lines A and B and 2,000-foot location on line B—Continued

	Line A wells (ft)		Line B wells (ft)		
Month	104	[1]535	[2]104	535	2,000
			1969		
January	37.48	39.73	....	23.25	29.13
February	36.97	39.34	....	22.64	28.63
March	38.65	40.73	....	24.75	31.05
April	37.66	39.96	....	23.10	30.32
May	38.27	40.67	....	25.00	31.88
June	38.00	40.05	....	23.88	30.80
July	37.51	39.54	....	23.83	30.70
August	39.19	41.56	....	25.56	32.16
September	38.53	41.38	....	25.00	31.69
October	38.84	41.29	....	25.13	31.58
November	38.26	40.66	....	24.56	31.05
December	37.68	40.30	....	24.40	30.79
			1970		
January	38.52	41.24	....	25.20	31.48
February	37.62	40.38	....	24.85	31.30
March	37.84	40.04	....	24.53	31.15
April	36.84	38.94	....	22.87	28.69
May	36.08	37.91	....	21.86	27.66
June	37.55	39.88	....	24.09	30.22
July	37.01	39.53	....	25.36	31.52
August	37.62	40.24	....	23.48	30.49
September	37.42	40.21	....	23.12	29.00
October	37.64	....	....	24.78	30.44
November	36.82	....	....	22.57	29.60
December	36.43	....	....	21.94	28.62
			1971		
January	36.27	....	....	21.68	28.02
February	37.06	....	....	21.70	27.97
March	37.00	....	....	21.53	27.60
April	36.31	....	....	21.27	26.79
May	36.38	....	....	21.64	27.09
June	37.68	....	....	23.96	29.01
July	37.61	....	....	24.64	29.68
August	37.87	....	....	24.64	30.96
September[3] ...	38.06	....	....	24.96	31.46

[1]Operation terminated September 1970.
[2]Operation terminated March 1964.
[3]All well records terminated September 1971.

Table A-25.—Monthly and annual evaporation, in inches, for rain-gage 3

Year	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1956	....	....	....	....	....	....	7.38	7.08	4.97	4.40	3.40	3.28	
1957	3.11	3.84	5.11	5.79	6.31	6.27	6.90	5.72	5.06	4.28	3.67	2.96	59.02
1958	2.83	3.61	4.58	5.53	6.34	7.00	6.78	5.87	5.62	4.65	3.33	2.77	58.91
1959	3.11	3.28	4.45	5.94	6.40	6.21	6.27	5.70	4.89	4.79	3.37	2.59	57.00
1960	3.52	3.57	5.18	5.96	6.99	5.73	6.91	5.80	4.55	4.52	3.36	2.81	58.90
1961	3.15	3.90	6.43	7.63	7.77	7.14	6.82	5.35	5.80	4.82	4.05	3.58	66.44
1962	3.50	4.74	6.65	6.55	7.78	5.44	6.76	5.38	4.90	4.88	3.39	2.75	62.72
1963	2.80	3.52	5.77	7.23	7.23	6.48	6.78	6.98	5.17	5.25	3.80	2.91	63.92
1964	2.29	3.71	6.05	6.43	6.87	6.98	6.52	6.38	5.43	4.25	2.96	3.18	61.05
1965	3.25	4.10	5.37	7.05	7.89	6.58	6.39	5.63	5.14	3.88	3.32	2.71	61.31
1966	2.46	3.25	4.75	6.32	6.53	6.32	5.83	5.56	4.62	4.12	3.49	2.92	56.17
1967	3.05	3.49	5.21	7.35	8.91	6.01	5.98	5.55	5.00	4.06	3.38	2.98	60.97
1968	2.73	3.74	5.90	6.75	7.09	5.30	5.69	5.22	4.54	4.54	3.52	2.99	58.01
1969	3.03	3.96	4.32	5.51	6.06	6.19	6.26	5.88	4.15	3.92	2.82	2.86	54.96
1970	2.52	3.30	4.80	6.31	7.29	5.29	5.88	6.02	5.18	4.14	3.56	3.19	58.48
1971	3.52	4.31	6.10	6.98	8.33	6.54	6.28	5.69	4.45	3.96	3.23	2.83	62.22
1972	3.25	3.76	6.04	6.50	6.69	6.60	6.33	5.67	5.53	4.65	3.10	3.01	61.13
1973	2.80	3.36	5.38	6.17	7.03	6.57	5.40	5.35	4.53	4.22	3.43	2.62	56.86
1974	2.66	3.70	5.60	6.70	6.58	5.75	5.20	5.02	5.04	4.13	2.87	2.40	55.65
1975	3.27	3.77	5.72	7.11	6.82	6.50	6.11	6.43	4.47	4.44	3.33	2.98	60.95
Average	3.01	3.73	5.44	6.52	7.10	6.26	6.32	5.81	4.95	4.40	3.37	2.92	59.72

Table A-26.—Mean monthly temperatures (°F) for Okeechobee hurricane gate 6, 1919–71

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Month											
1919	62.6	63.9	69.8	69.0	76.2	79.0	82.7	82.9	80.3	79.4	(1)	(1)
1920	(1)	(1)	(1)	(1)	74.0	78.1	80.4	81.1	80.4	(1)	(1)	(1)
1921	(1)	(1)	(1)	74.0	75.9	79.4	80.6	81.2	61.1	(1)	69.7	66.4
1922	64.2	67.7	69.4	73.0	76.4	79.5	80.6	81.6	80.2	78.7	71.6	63.4
1923	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
1924	(1)	(1)	(1)	72.6	76.1	80.6	81.0	82.4	79.2	(1)	67.6	67.5
1925	68.0	65.3	66.8	69.8	74.0	79.6	80.0	81.2	81.4	76.7	68.9	(1)
1926	(1)	62.8	63.6	70.6	74.6	78.0	80.4	81.5	80.4	74.5	66.0	65.8
1927	60.0	67.8	65.0	(1)	76.6	82.0	(1)	(1)	79.7	75.7	(1)	62.4
1928	59.5	66.2	69.2	70.8	72.8	79.7	81.2	82.2	(1)	(1)	(1)	(1)
1929	(1)	69.8	70.8	73.0	76.7	79.4	80.4	81.6	81.2	74.8	73.8	(1)
1930	68.0	66.1	65.8	72.1	77.0	78.6	82.4	81.8	81.6	73.4	66.1	59.6
1931	59.8	60.3	60.6	67.9	73.4	78.4	(1)	80.9	79.6	75.8	69.6	70.6
1932	66.3	69.4	64.0	69.3	75.2	80.2	82.6	82.3	81.0	76.5	66.4	66.6
1933	65.0	67.4	64.3	(1)	(1)	78.2	80.8	81.8	(1)	(1)	65.2	63.7
1934	63.2	61.3	66.8	70.1	74.8	78.6	80.0	78.8	78.1	(1)	67.2	60.5
1935	62.2	61.4	68.6	71.4	76.6	78.0	79.3	80.8	79.5	75.2	68.1	55.0
1936	63.2	62.2	66.0	70.4	73.6	76.8	80.1	80.7	79.6	77.0	66.6	66.0
1937	70.3	63.0	64.8	69.3	(1)	76.8	79.0	80.8	79.8	74.3	66.0	63.0
1938	62.4	65.8	70.0	70.6	76.7	77.5	80.6	81.9	79.4	73.3	70.4	63.3
1939	62.4	69.2	70.4	71.6	75.0	79.6	80.6	80.2	81.2	78.0	67.0	62.7
1940	54.4	59.4	66.0	69.0	72.6	80.5	82.4	80.7	78.3	72.7	68.3	67.8
1941	61.6	60.8	64.1	71.9	73.8	79.7	81.8	83.7	80.8	78.4	70.7	67.6
1942	59.8	57.8	64.3	70.2	74.8	80.8	82.4	82.8	82.1	76.2	68.6	65.1
1943	63.4	58.9	66.9	69.8	76.8	80.4	80.9	82.4	80.8	73.0	67.4	63.2
1944	60.1	66.5	69.9	74.5	76.3	80.6	81.6	81.2	80.3	72.6	65.3	59.5
1945	60.4	65.8	70.2	74.2	74.5	80.4	80.8	82.0	80.7	77.2	68.0	63.0
1946	64.6	65.2	69.8	72.2	78.2	79.3	81.4	81.8	80.7	76.9	74.0	68.6
1947	69.6	57.2	64.3	76.0	76.7	78.8	79.8	80.6	78.7	75.7	71.6	66.3
1948	61.4	67.6	71.8	71.6	75.8	78.6	79.0	79.6	78.2	73.7	74.3	68.3
1949	65.5	70.3	67.1	72.3	76.6	78.9	80.6	80.6	(1)	75.7	63.0	65.6
1950	66.6	65.2	69.9	68.0	77.0	80.0	78.2	78.7	78.2	75.2	66.7	61.0
1951	62.2	62.5	67.3	70.2	75.6	79.5	79.8	83.0	82.3	77.3	69.3	69.4
1952	66.9	64.7	70.7	68.5	76.5	80.9	(1)	(1)	81.8	74.4	69.8	62.0
1953	63.0	66.4	70.9	73.1	79.0	(1)	(1)	(1)	(1)	(1)	(1)	(1)
1954	(1)	(1)	64.8	74.5	75.8	79.4	80.7	81.1	79.6	74.0	66.5	60.3
1955	61.5	62.5	68.6	74.0	78.7	80.1	82.5	83.3	81.9	75.4	69.4	65.1
1956	58.0	68.2	68.0	72.5	79.7	80.7	83.3	83.6	80.4	76.6	67.5	66.6
1957	65.2	69.2	68.2	75.8	79.1	82.3	(1)	81.9	82.0	74.6	72.6	61.6
1958	56.9	54.8	66.0	72.7	(1)	(1)	(1)	(1)	(1)	(1)	73.7	64.9
1959	59.4	70.9	67.4	73.7	(1)	79.8	80.2	80.3	79.4	78.8	70.7	61.4
1960	62.0	60.9	63.1	71.5	74.6	78.4	81.4	81.1	79.7	77.7	71.7	59.9
1961	59.5	64.4	69.5	69.5	75.1	79.0	81.1	81.2	80.1	73.9	70.1	64.6
1962	62.7	66.7	65.5	69.9	76.2	78.5	81.8	81.4	79.8	75.8	64.2	52.1
1963	60.3	59.4	69.6	72.4	75.8	79.5	(1)	82.0	80.3	75.0	67.4	57.4
1964	59.9	60.2	70.3	73.2	76.5	80.4	81.0	81.8	80.3	73.7	71.3	65.8
1965	63.3	65.7	68.6	74.0	75.9	79.0	80.4	81.3	80.6	76.1	71.2	63.7
1966	60.7	62.0	66.0	70.6	77.2	79.4	81.7	81.8	81.8	77.6	69.3	61.7
1967	66.1	62.2	68.7	72.6	77.1	79.1	82.0	80.9	80.1	74.2	69.3	68.8
1968	64.8	59.8	(1)	75.4	79.1	80.8	82.3	83.0	81.9	77.5	67.0	60.1
1969	61.9	59.5	60.8	(1)	75.9	81.1	82.5	80.8	79.8	77.7	65.5	58.5
1970	57.2	59.8	66.1	75.0	75.4	79.0	81.4	82.0	81.9	76.5	(1)	(1)
1971	(1)	64.5	64.8	70.0	(1)	78.9	(1)	(1)	(1)	(1)	(2)	
	Mean											
	62.6	63.9	67.2	71.8	76.0	79.4	81.0	81.5	80.4	75.8	68.8	62.4
	Number of years											
	45	48	48	48	47	50	44	47	46	43	45	44

[1]Missing record.
[2]Discontinued.

Table A-27.—Mean monthly maximum and minimum temperatures (°F) for Okeechobee hurricane gate 6, 1919–71

Year	Jan. Max.	Jan. Min.	Feb. Max.	Feb. Min.	Mar. Max.	Mar. Min.	Apr. Max.	Apr. Min.	May Max.	May Min.	June Max.	June Min.	July Max.	July Min.	Aug. Max.	Aug. Min.	Sept. Max.	Sept. Min.	Oct. Max.	Oct. Min.	Nov. Max.	Nov. Min.	Dec. Max.	Dec. Min.
1919	73.8	51.4	73.4	54.4	79.8	59.9	82.1	56.0	88.4	63.9	87.4	70.5	92.8	72.6	92.3	73.5	89.1	71.5	88.2	70.6	([1])	([1])	([1])	([1])
1920	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	85.5	62.5	89.3	66.9	90.8	70.0	([1])	([1])	90.2	70.5	([1])	([1])	([1])	([1])	([1])	([1])
1921	([1])	([1])	([1])	([1])	([1])	([1])	84.5	63.5	85.8	66.0	90.7	67.6	90.9	70.4	92.3	70.0	92.6	69.6	([1])	63.6	85.2	54.2	81.1	51.6
1922	79.5	48.9	84.9	50.5	85.1	53.8	88.4	57.5	89.4	63.4	90.1	68.9	90.8	70.4	90.8	72.3	90.6	69.7	88.2	69.2	82.0	61.2	76.7	50.1
1923	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])
1924	([1])	([1])	([1])	([1])	([1])	([1])	83.4	61.7	87.9	64.3	91.4	69.8	90.1	71.9	91.5	73.3	87.3	71.0	([1])	66.6	78.0	57.1	78.3	56.7
1925	77.3	58.7	76.8	53.8	78.2	55.5	81.4	58.1	84.4	63.6	88.4	70.7	88.9	71.1	89.7	72.6	90.8	72.0	86.7	66.7	78.6	59.2	([1])	([1])
1926	([1])	([1])	74.7	50.8	75.7	51.6	81.1	60.2	86.5	62.6	88.2	67.7	89.4	71.5	90.6	72.4	89.0	71.8	84.7	64.3	77.4	54.7	76.9	54.6
1927	72.1	47.9	80.2	55.3	77.5	52.5	83.6	([1])	88.2	65.0	92.5	71.4	([1])	71.5	([1])	71.2	88.7	70.7	85.2	66.2	([1])	([1])	74.1	50.6
1928	71.3	47.7	77.6	54.7	81.2	57.3	81.6	59.9	85.5	60.2	89.4	70.0	89.8	72.7	90.9	73.6	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])
1929	([1])	([1])	81.3	51.3	85.1	60.1	85.4	60.7	86.8	66.6	88.2	70.5	88.7	72.0	90.1	73.2	89.0	73.4	84.2	65.4	84.4	61.3	([1])	([1])
1930	80.0	56.0	78.6	53.6	77.7	53.9	82.8	61.4	86.8	67.2	86.7	70.6	91.8	72.9	92.2	71.3	90.5	72.6	83.6	63.3	76.6	55.6	70.9	48.3
1931	71.6	48.0	72.2	48.9	72.8	48.5	78.7	57.1	84.7	62.2	90.1	66.8	([1])	71.3	91.4	70.4	89.2	69.9	86.0	65.7	82.5	56.8	82.6	58.7
1932	78.1	54.5	82.6	56.1	76.6	51.4	82.9	54.7	88.4	62.1	88.0	72.5	92.5	72.7	91.4	73.2	89.6	72.5	86.6	66.4	76.6	56.3	79.2	54.9
1933	77.0	52.9	79.4	55.5	78.0	50.6	([1])	([1])	([1])	([1])	89.1	67.4	90.9	70.6	90.8	72.7	([1])	([1])	([1])	([1])	77.8	52.6	76.2	51.2
1934	76.8	49.5	75.0	47.6	78.8	54.7	82.5	57.7	84.4	65.3	86.8	70.3	88.7	71.2	87.5	70.2	86.6	69.6	([1])	64.1	79.7	54.7	72.2	48.8
1935	76.1	48.2	73.6	48.9	83.1	54.0	84.1	58.7	88.3	64.9	89.4	66.5	89.3	69.3	92.1	69.6	88.4	70.6	84.3	66.0	79.4	56.8	68.4	41.6
1936	78.9	52.7	72.7	51.6	76.7	55.3	82.2	58.5	84.8	62.4	86.1	67.6	89.5	70.7	89.9	71.5	88.9	70.2	86.0	67.9	77.3	56.0	76.8	55.1
1937	81.3	59.3	74.7	51.2	77.7	52.0	80.3	58.3	([1])	61.8	86.8	66.8	89.1	69.0	90.0	71.5	88.1	71.6	82.7	65.9	75.3	56.6	72.7	53.2
1938	72.5	52.2	78.2	53.4	82.3	57.8	82.6	58.6	90.4	63.0	87.8	67.2	89.3	71.9	91.7	72.1	89.0	69.8	83.1	63.5	79.8	61.1	75.3	51.3
1939	75.4	49.3	81.6	56.9	84.4	56.3	82.7	60.5	84.8	65.3	89.4	69.7	89.9	71.4	88.6	72.4	89.9	72.4	86.0	69.9	76.5	61.0	75.4	50.0
1940	65.7	43.2	70.9	47.8	76.7	55.2	79.8	58.2	86.2	59.1	89.4	73.6	91.8	73.2	90.7	70.7	85.0	71.6	83.4	62.0	79.7	56.9	79.1	56.4
1941	72.9	50.3	72.1	49.5	75.2	53.0	82.5	61.3	86.8	60.7	91.3	68.1	91.0	72.5	94.0	73.4	90.0	71.6	87.6	69.1	80.1	61.3	77.4	57.8
1942	71.0	48.5	68.6	47.1	75.4	53.2	80.7	59.8	86.1	63.6	89.2	72.5	90.8	74.1	92.1	73.5	90.8	73.4	([1])	([1])	81.3	55.8	77.3	52.6
1943	77.9	48.9	75.7	42.1	88.1	52.7	84.2	55.5	92.6	59.0	95.3	65.5	95.4	66.4	96.4	68.5	92.4	69.2	84.4	61.5	78.3	56.5	75.8	50.7
1944	73.6	46.6	81.2	51.8	83.5	56.3	86.7	62.3	90.7	61.9	95.7	65.5	94.9	68.4	92.7	69.8	91.9	68.7	([1])	([1])	77.6	53.0	74.2	44.8
1945	74.1	46.6	79.8	51.9	([1])	([1])	89.5	59.0	91.1	57.9	([1])	([1])	88.9	72.7	89.3	74.8	87.6	73.8	84.0	70.3	76.5	59.4	70.6	55.3
1946	72.9	56.3	74.4	56.1	78.4	61.1	82.9	61.4	86.2	70.2	86.6	72.0	88.8	74.1	89.6	74.0	87.7	73.7	84.1	69.7	81.1	66.9	([1])	([1])
1947	76.8	62.5	66.9	47.5	73.8	50.6	83.7	68.4	84.4	69.0	84.8	72.9	85.5	74.1	87.4	73.9	84.7	72.7	80.8	70.6	77.2	66.1	([1])	([1])
1948	68.4	54.4	75.1	60.2	78.3	65.4	79.5	63.7	83.3	68.2	86.4	70.7	86.4	71.7	86.7	72.5	84.5	72.0	80.4	67.0	80.9	67.6	75.4	61.1
1949	74.5	56.5	79.4	61.4	77.1	57.0	81.3	63.3	85.2	67.9	86.6	71.2	87.0	74.2	86.6	74.5	([1])	([1])	81.9	69.5	72.0	53.9	73.5	57.7
1950	74.0	59.1	75.1	55.3	78.5	61.2	77.2	58.7	84.9	69.1	87.3	72.7	85.5	70.9	86.3	71.0	84.9	71.5	82.0	68.4	75.3	58.0	70.1	51.9
1951	71.0	53.4	71.5	53.5	75.7	58.8	78.6	61.8	85.3	65.9	88.2	70.7	86.8	72.8	89.8	76.1	89.7	74.8	83.8	70.8	77.5	61.1	77.0	61.7
1952	75.2	58.5	72.9	56.4	78.1	63.3	77.5	59.5	84.5	68.5	88.9	72.8	([1])	([1])	([1])	([1])	88.9	74.6	80.0	68.7	77.3	62.2	70.9	53.1
1953	70.7	55.3	74.2	58.5	79.2	62.5	80.5	65.6	86.5	71.4	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])
1954	([1])	([1])	([1])	([1])	73.8	55.7	82.8	66.1	83.9	67.6	86.1	72.7	87.5	73.9	88.2	73.9	85.5	73.7	81.4	66.6	73.9	59.0	69.2	51.4
1955	70.1	52.9	69.6	55.4	78.1	59.1	80.9	67.1	85.4	72.0	85.9	74.3	87.1	77.9	88.6	77.9	87.7	76.1	82.3	68.5	77.6	61.1	72.6	57.5
1956	67.2	48.7	75.9	60.5	80.7	54.2	80.3	64.7	85.3	74.0	87.0	74.4	88.7	77.9	89.8	77.4	85.8	75.0	82.4	70.8	75.3	59.6	75.1	58.0
1957	73.0	57.4	76.7	61.7	75.4	60.9	80.8	70.8	83.5	74.7	86.5	78.1	([1])	79.0	86.9	76.8	86.8	77.1	81.1	68.0	78.3	66.8	70.3	52.9
1958	63.6	50.1	62.8	42.8	72.5	59.5	78.4	66.9	83.2	71.4	88.2	([1])	88.3	([1])	88.5	([1])	88.2	([1])	83.1	([1])	80.8	66.6	73.0	56.8
1959	68.6	50.1	77.9	63.8	74.3	60.5	80.4	66.9	84.0	([1])	86.6	73.2	87.0	73.3	87.0	73.6	85.9	72.8	84.8	72.7	78.2	63.1	70.3	52.5
1960	71.6	52.4	70.4	51.4	72.4	54.0	79.6	63.4	83.3	65.8	85.3	71.4	88.4	74.4	88.1	74.1	85.4	73.9	84.7	70.6	80.1	63.3	69.7	50.1
1961	68.7	50.2	73.3	55.4	79.0	60.0	79.6	59.3	83.6	66.5	86.6	71.3	88.8	73.4	88.5	73.8	88.0	72.1	82.8	65.0	79.3	60.8	74.0	55.2
1962	72.7	52.6	76.5	56.8	75.6	55.6	78.7	61.1	85.0	67.3	85.1	71.8	89.0	74.7	88.0	74.7	86.5	73.1	84.3	67.2	73.1	55.3	67.8	48.4

See footnote at end of table.

Table A-27.—Mean monthly maximum and minimum temperatures (°F) for Okeechobee hurricane gate 6, 1919–71 —Continued

	Month																							
	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
Year	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1963	69.5	51.1	68.9	49.8	77.6	61.5	82.0	62.8	83.6	67.9	86.7	72.3	(1)	(1)	90.4	73.5	87.3	73.3	84.4	65.5	76.0	58.8	67.0	47.8
1964	68.3	51.4	69.5	50.9	79.4	61.1	81.9	64.5	84.7	68.3	88.0	72.7	88.4	73.5	89.5	74.1	87.1	73.4	80.9	66.4	79.8	62.7	74.7	56.9
1965	75.3	51.2	76.0	55.4	77.9	59.3	84.3	63.7	87.7	64.1	88.6	69.4	88.7	72.0	89.9	72.6	89.2	71.9	85.8	66.3	81.8	60.5	75.2	52.1
1966	71.4	50.0	72.1	51.8	76.7	55.2	80.5	60.6	85.5	68.9	87.6	71.2	89.1	74.3	90.2	73.3	90.2	73.4	87.5	67.6	82.1	56.5	74.2	49.1
1967	78.1	54.0	73.7	56.0	78.8	58.6	82.8	62.4	86.5	67.3	86.9	71.3	89.1	74.8	87.7	74.0	88.3	71.9	82.5	65.9	78.4	60.2	77.7	59.9
1968	74.2	55.4	72.1	67.5	(1)	54.6	85.3	65.5	87.9	70.3	88.6	72.9	89.9	74.7	90.7	75.3	89.8	73.9	87.5	67.4	79.1	54.8	69.7	50.4
1969	71.1	52.6	72.3	46.6	71.4	50.2	(1)	(1)	83.5	68.3	88.2	74.0	89.7	75.2	87.6	74.0	85.6	74.0	83.5	71.8	74.4	56.6	68.4	48.6
1970	67.2	47.2	69.6	50.0	73.1	59.1	82.6	67.3	84.0	67.0	86.7	71.3	89.6	73.1	89.5	74.5	89.3	74.5	84.5	68.5	(1)	(1)	(1)	(1)
1971	(1)	(1)	74.2	54.8	76.7	52.8	81.5	58.5	(1)	(1)	88.5	69.3	(1)	(1)	(1)	(1)	(1)	(1)	86.2	67.2	80.5	58.8	80.4	58.3
	Mean																							
	73.0	52.1	74.7	53.0	77.8	56.4	82.0	61.5	86.0	65.8	88.3	70.6	89.4	72.6	89.9	73.0	88.3	72.3	84.1	67.3	78.3	59.1	74.1	53.2

[1]Missing record.

Table A-28.—Results of water-quality analyses on samples from various locations in watershed W-2

	Measurement						
Date	Conductivity (μmhos/cm)	Chloride (mg/l)	Nitrate N (mg/l)	Available P (mg/l)	H+ ion (pH)	Turbidity (JTU)[1]	Streamflow (ft^3/s)[2]
				Site 1[3]			
4/19/72	163	25	0.275	0.08	7.9	4.6	....
5/2/72	210	50	([4])	.00	7.9	4.3	....
5/16/72	250	50	([4])	.05	([4])	11.0	....
5/30/72	490	100	.10	.06	7.7	6.5	....
6/13/72	482	150	.25	.02	([4])	2.7	....
6/27/72	500	100	.90	.01	8.0	1.6	....
7/11/72	460	50	.20	.05	7.8	9.0	....
7/25/72	790	50	.25	.08	7.9	2.2	....
8/1/72	760	50	.67	.32	7.2	7.9	
Average	456	69	0.38	0.07	7.8	5.5	
				Site 4[3]			
4/19/72	([4])	([4])	([4])	([4])	([4])	([4])	....
5/2/72	620	200	([4])	0.00	7.8	3.3	....
5/16/72	([4])	([4])	([4])	([4])	([4])	([4])	....
5/30/72	1,500	300	0.50	.04	8.0	3.0	....
6/13/72	1,480	250	.75	.02	([4])	4.0	....
6/27/72	1,600	500	1.1	.14	8.0	2.5	....
7/11/72	([4])	([4])	([4])	([4])	([4])	([4])	....
7/25/72	2,650	200	.20	.51	8.1	8.0	....
8/1/72	2,950	250	.72	.55	8.0	9.4	
Average	1,800	283	0.65	0.21	8.0	5.0	....
				Site 7[3]			
4/19/72	190	500	0.60	0.03	8.2	16.0	....
5/2/72	155	50	([4])	.06	7.8	6.3	....
5/16/72	165	50	([4])	.03	([4])	10.0	....
5/30/72	520	50	1.0	.02	7.8	4.3	....
6/13/72	585	100	.95	.02	([4])	2.9	....
6/27/72	750	100	.45	.02	7.4	5.0	....
7/11/72	885	100	.50	.06	7.7	12.0	....
7/25/72	1,010	100	.25	.92	7.3	27.0	....
8/1/72	990	100	4.50	.31	7.4	26.0	
Average	583	128	1.18	0.16	7.7	12.2	....
				Site 2[5]			
4/19/72	360	150	0.525	0.30	7.3	2.3	7.3
5/2/72	340	50	([4])	.47	7.5	1.6	6.2
5/16/72	330	50	([4])	.30	([4])	1.0	5.1
5/30/72	364	100	.40	.22	7.3	2.5	11
6/13/72	390	150	1.40	.26	([4])	1.2	17
6/27/72	640	100	1.40	.44	7.2	1.5	45
7/11/72	370	100	.55	.22	7.3	2.0	56
7/25/72	540	100	.65	4.44	7.2	1.1	12
8/1/72	605	100	.55	2.05	7.4	1.2	8.4
9/5/72	90	5	.05	1.53	([4])	1.3	294
10/3/72	201	150	.11	1.32	([4])	1.5	20
11/7/72	280	305	.07	3.41	([4])	.8	7.5
12/5/72	339	50	.13	.41	([4])	1.0	9
1/3/73	320	150	.13	.33	([4])	.5	7.3
Average	369	118	0.50	1.12	7.3	1.5	31.4

See footnotes at end of table.

Table A-28.—Results of water-quality analyses on samples from various locations in watershed W-2—Continued

Date	Measurement						
	Conductivity (μmhos/cm)	Chloride (mg/l)	Nitrate N (mg/l)	Available P (mg/l)	H+ ion (pH)	Turbidity (JTU)[1]	Streamflow (ft³/s)[2]
				Site 3[5]			
4/19/72	225	50	0.40	0.45	7.8	5.4	1.3
5/2/72	375	100	([4])	.25	8.0	3.2	.88
5/16/72	183	100	([4])	.63	([4])	4.0	1.4
5/30/72	330	100	.50	.22	7.2	6.5	.08
6/13/72	570	100	.70	.10	([4])	3.4	2.2
6/27/72	730	100	1.3	.22	7.3	2.8	4.3
7/11/72	380	150	.45	.04	7.3	5.6	3.8
7/25/72	730	50	.65	2.23	7.7	7.0	1.4
8/1/72	310	250	.30	.26	7.7	3.8	3.5
9/5/72	59	100	.06	1.21	([4])	.8	78
10/3/72	170	150	.58	1.18	([4])	1.3	2.4
11/7/72	460	100	.06	.16	([4])	22.0	2.8
12/5/72	330	100	.22	.22	([4])	1.2	3
1/3/73	250	450	.20	.32	([4])	.9	2.4
Average	364	136	0.45	0.54	7.6	4.8	7.5
				Site 5[5]			
4/19/72	1,120	75	0.325	0.30	7.4	6.7	2.1
5/2/72	1,330	500	([4])	.65	7.5	2.0	2.1
5/16/72	2,500	900	([4])	1.23	([4])	4.0	2.1
5/30/72	1,150	350	.35	.34	7.5	8.2	2.7
6/13/72	1,100	400	.75	.12	([4])	2.3	9.1
6/27/72	1,650	300	1.3	.20	7.4	2.4	6.9
7/11/72	850	500	.50	.08	7.3	2.2	9.6
7/25/72	700	700	.25	2.04	7.5	4.8	3.9
8/1/72	1,800	900	.36	2.60	7.7	3.0	2.4
9/5/72	500	100	.14	.37	([4])	1.3	26
10/3/72	1,400	400	.18	.07	([4])	.8	4.6
11/7/72	3,130	1,500	.25	.30	([4])	2.0	2.7
12/5/72	2,050	750	.09	.40	([4])	.6	3.9
1/3/73	2,180	700	.07	.32	([4])	.7	3.9
Average	1,533	577	0.38	0.64	7.5	2.9	11.0
				Site 9[6]			
4/19/72	440	50	0.300	0.30	7.5	2.6	7.3
5/2/72	300	150	([4])	.42	7.8	1.3	6.2
5/16/72	380	100	([4])	.32	([4])	1.3	5.1
5/30/72	350	100	.95	.34	7.4	2.5	11
6/13/72	365	100	.95	.22	([4])	1.5	17
6/27/72	670	100	1.1	.38	7.2	1.4	45
7/11/72	450	200	.70	.14	7.4	2.5	56
7/25/72	325	100	.60	5.03	7.4	1.6	12
8/1/72	480	150	.47	2.15	7.8	2.0	8.4
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	294
10/3/72	([4])	([4])	([4])	([4])	([4])	([4])	20
11/7/72	130	200	.11	.42	([4])	1.3	7.5
12/5/72	([4])	([4])	([4])	([4])	([4])	([4])	9
1/3/73	([4])	([4])	([4])	([4])	([4])	([4])	7.3
Average	418	125	0.65	0.97	7.5	1.8	31.4

See footnotes at end of table.

Table A-28.—Results of water-quality analyses on samples from various locations in watershed W-2—Continued

Date	Measurement						
	Conductivity (μmhos/cm)	Chloride (mg/l)	Nitrate N (mg/l)	Available P (mg/l)	H+ ion (pH)	Turbidity (JTU)[1]	Streamflow (ft^3/s)[2]
				Site 6[6]			
4/19/72	242	25	0.400	0.12	9.2	3.6	....
5/2/72	138	100	([4])	.05	7.5	4.2	....
5/16/72	200	50	([4])	.22	([4])	2.5	....
5/30/72	700	50	.85	.10	7.3	1.5	....
6/13/72	875	100	.90	.14	([4])	1.6	....
6/27/72	810	100	1.4	.16	7.1	([4])	....
7/11/72	690	250	.50	.12	7.2	3.9	....
7/25/72	500	150	.65	.92	7.3	3.6	....
8/1/72	880	200	.70	.66	7.3	6.0	....
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	....
10/3/72	95	50	.18	.18	([4])	.8	....
11/7/72	210	150	.24	.51	([4])	1.2	....
12/5/72	167	50	.20	.20	([4])	1.5	....
1/3/73	240	100	.37	.13	([4])	.6	....
Average	442	106	0.58	0.27	7.6	2.6	....
				Site 11[6]			
4/19/72	240	50	0.400	0.65	7.0	11.0	....
5/2/72	328	100	([4])	2.70	7.5	120.0	....
5/16/72	270	100	([4])	2.84	([4])	16.0	....
5/30/72	325	50	1.0	1.30	7.4	15.0	....
6/13/72	545	100	1.3	.78	([4])	4.1	....
6/27/72	500	250	1.0	1.06	7.0	9.0	....
7/11/72	350	100	1.4	2.20	6.9	23.0	....
7/25/72	430	200	.95	16.75	7.1	23.0	....
8/1/72	580	1,150	2.70	18.80	6.9	20.0	....
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	....
10/3/72	230	100	.96	4.15	([4])	3.2	....
11/7/72	229	100	.15	5.09	([4])	1.3	....
12/5/72	290	150	.26	3.46	([4])	4.3	....
1/3/73	290	100	.42	3.06	([4])	.6	....
Average	354	196	0.96	4.83	7.1	19.3	....
				Site 12[6]			
4/19/72	([4])	([4])	([4])	([4])	([4])	([4])	....
5/2/72	199	100	([4])	.43	7.3	4.3	....
5/16/72	160	100	([4])	.85	([4])	3.9	....
5/30/72	530	100	.15	.20	7.3	3.5	....
6/13/72	790	100	1.25	.58	([4])	4.3	....
6/27/72	650	200	1.0	.34	6.9	2.9	....
7/11/72	530	150	.20	.16	6.8	3.8	....
7/25/72	641	150	.75	4.79	6.8	9.0	....
8/1/72	720	250	.92	1.65	6.8	10.0	....
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	....
10/3/72	180	100	.37	2.44	([4])	.7	....
11/7/72	190	50	.20	.57	([4])	.7	....
12/5/72	199	150	.46	1.23	([4])	2.2	....
1/3/73	281	200	.37	.92	([4])	.4	....
Average	422	138	0.57	1.18	7.0	3.5	....

See footnotes at end of table.

Table A-28.—Results of water-quality analyses on samples from various locations in watershed W-2—Continued

Date	Measurement						
	Conductivity (μmhos/cm)	Chloride (mg/l)	Nitrate N (mg/l)	Available P (mg/l)	H+ ion (pH)	Turbidity (JTU)[1]	Streamflow (ft³/s)[2]
				Site 8[6]			
4/19/72	1,320	500	0.500	0.03	8.1	3.1	....
5/2/72	1,320	550	([4])	.00	8.1	3.2	....
5/16/72	2,200	900	([4])	.06	([4])	2.0	....
5/30/72	700	600	.90	.06	7.9	([4])	
6/13/72	700	650	.85	.06	([4])	2.7	....
6/27/72	1,400	400	1.0	.12	7.9	2.2	....
7/11/72	1,100	350	.40	.08	7.7	6.3	....
7/25/72	590	1,100	.40	.54	7.9	3.2	....
8/1/72	1,800	500	.40	.31	8.0	3.6	....
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	....
10/3/72	2,150	1,050	.07	.09	([4])	.7	....
11/7/72	3,800	1,900	.07	.01	([4])	1.5	....
12/5/72	1,840	700	.09	.03	([4])	1.0	....
1/3/73	2,500	800	.22	.01	([4])	.4	....
Average	1,684	769	0.45	0.11	7.9	2.4	....
				Site 15[6]			
4/19/72	1,650	500	0.475	0.14	8.3	4.1	....
5/2/72	2,000	800	([4])	.20	8.7	3.6	....
5/16/72	3,400	1,500	([4])	.15	([4])	2.3	....
5/30/72	1,400	1,150	.75	.01	8.1	3.0	....
6/13/72	1,700	250	1.15	.10	([4])	3.5	....
6/27/72	1,500	250	.95	.13	7.8	2.5	....
7/11/72	2,500	1,500	.50	.05	8.1	2.5	....
7/25/72	3,400	1,800	.20	.79	7.9	2.3	....
8/1/72	1,070	2,600	.32	.31	7.9	2.0	....
9/5/72	([4])	([4])	([4])	([4])	([4])	([4])	....
10/3/72	2,620	1,200	.11	.06	([4])	.7	....
11/7/72	3,600	1,800	.13	.06	([4])	2.0	....
12/5/72	4,450	1,800	.07	.005	([4])	6.0	....
1/3/73	3,860	850	.21	.02	([4])	.7	....
Average	2,250	1,235	0.44	0.16	8.1	2.7	....

[1]Jackson Turbidity Units.

[2]Not applicable for sites 1, 4, and 7. Streamflow not measured at sites 6, 8, 11, 12, and 15. Averages for sites 2, 3, 5, and 9 were based on whole annual record.

[3]See figure 1.3 for location of ground-water well.

[4]No record.

[5]See figure 1.3 for location of streamflow gaging station.

[6]See figure 1.3 for location of open channel sampling site.

Table A-29.—Nitrate-nitrogen (N) and orthophosphate-phosphorus (P) concentrations (mg/l), Taylor Creek watershed, 1974

Date	Concentrations at site No.[1]—													
	1		2		3		4		5		6		7	
	N	P	N	P	N	P	N	P	N	P	N	P	N	P
Mar. 19	0.02	0.28	0.08	0.33	....	....	0.03	0.05	0.04	0.02	0.29	0.04	0.05	
Mar. 26	.26	.17	.25	.42	0.19	3.10	.32	<.06	.34	<.06	.13	.39	....	....
Apr. 2	.52	1.68	.08	.15	.30	1.68	1.23	.74	.11	.11	....	.26	....	....
Apr. 9	.60	.39	4.38	.06	.38	.74	.23	.37	1.67	<.06	.05	.08	....	....
Apr. 16	<.04	.57	1.28	.39	.43	2.12	.17	<.06	<.04	<.06	<.04	.42	....	....
Apr. 23	.04	.49	1.41	.37	1.75	1.90	.05	.06	<.04	<.06	<.04	.49	....	....
May 1	<.04	.30	<.04	.33	.80	1.86	<.04	<.06	<.04	<.06	<.04	.43	....	....
May 7	<.04	.29	.15	.49	.20	1.99	.24	<.06	.06	<.06	.08	.48	....	....
May 14	.16	.46	.16	2.02	<.04	.11	<.04	<.06	<.04	.39	<.04	.12	....	....
May 21	.19	.24	.15	.35	<.04	2.09	.18	.6	....	....	.40	.42	....	....
May 28	.11	.06	.10	.44	.29	1.36	.04	.08	<.04	<.06	.05	.25	....	....
June 4	.26	.17	.23	.42	.19	3.10	.32	<.06	.34	<.06	.13	.39	....	....
June 11	....	....	....	....	....	....	....	....	....	....	....	....	....	....
June 18	<.04	.09	.04	.57	.06	.37	<.04	.32	.26	.47	<.04	3.13	....	....
July 9	.00	.67	.13	2.76	1.20	3.26	.17	.34	<.04	.61	.52	1.42	....	....
July 16	....	....	....	....	....	....	....	....	.15	1.23	....	....	....	....
July 23	....	....	....	....	.08	3.19	....	....	....	....	.04	.58	....	....
July 30	<.04	.40	.9	1.38	1.83	2.86	.04	.29	.20	.99	.14	.62	....	....
Aug. 6	.00	.25	....	....	.10	2.65	....	....	.09	.64	.40	.79	....	....
Aug. 20	<.04	.35	.10	1.31	.13	2.59	<.04	.46	.12	.78	.09	.81	....	....
Sept. 3	.08	.50	.50	1.07	.19	2.78	.07	.18	.63	.31	1.19	....	....	
Sept. 17	1.01	.84	.31	2.62	.34	.37	.13	.16	.55	.55	.26	.21	.14	.14
Sept. 24	.31	.17	1.63	.57	.10	2.41	<.04	.21	.22	.44	.04	.72	.08	.24
Oct. 1	<.04	.17	<.04	1.02	.16	3.26	.69	.23	<.04	.73	.08	.43	.05	.41
Oct. 29	1.16	.51	.74	1.26	.34	.05	.18	.11	.13	.07	.44	.51	.28	.20
Nov. 5	.06	.15	.64	1.41	.13	.18	.08	.17	.12	.54	.14	.19	.24	.54
Nov. 19	1.41	.53	.55	1.25	.26	.51	.08	.16	.08	.08	.17	.47	.09	.22
Dec. 3	.12	.13	.46	.49	2.40	1.19	.09	.08	.14	.07	.38	.42	.47	.35
Dec. 17	.00	.05	.04	.59	1.47	3.10	.04	.04	.02	.04	.00	.29	.01	.09
Dec. 31	.01	.18	.17	.65	.56	1.81	.01	.05	.08	.43	....	....	.01	.03
Average.........	0.24	0.37	0.57	0.87	0.52	1.88	0.18	0.22	0.19	0.34	0.16	0.59	0.14	0.23

[1]1=Watershed W-3, Taylor Creek at S.R. 68, 2=Little Bimini Creek at Potter Rd., 3=watershed W-13, Otter Creek at Potter Rd. (S-13), 4=Williamson Main Ditch, 5=Williamson East Lateral Ditch, 6=watershed W-2A, Taylor Creek at U.S. Highway 441, 7=watershed W-5, Williamson Ditch at S-7.

Table A-30.—Electrical conductivity (EC, μmhos/cm) and pH, Taylor Creek watershed, 1974

	EC and pH at site No.[1]—													
	1		2		3		4		5		6		7	
Date	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH
Mar. 19	0.32	8.3	0.26	8.3	....	....	3.85	8.2	3.30	8.2	1.32	8.0	....	....
Mar. 26	.25	7.1	.29	7.0	0.30	7.2	6.00	7.3	5.5	7.5	2.14	7.3	....	....
Apr. 2	.26	8.0	.24	7.5	.44	7.6	5.00	7.9	5.30	7.9	2.50	8.2	....	....
Apr. 9	.26	7.8	.32	7.6	.34	7.4	4.80	7.7	4.60	7.9	1.52	7.6	....	....
Apr. 16	.25	7.0	.31	7.0	.34	6.7	5.70	7.3	5.20	7.6	1.50	7.1	....	....
Apr. 23	.01	6.8	.26	6.8	.26	6.3	2.80	7.1	4.91	7.1	.56	7.1	....	....
May 1	....	6.9	....	6.9	....	6.7	....	7.2	....	7.1	....	7.6	....	....
May 7	.08	7.7	.02	7.5	.36	7.5	3.19	7.8	2.00	7.6	.52	7.8	....	....
May 14	.30	7.6	.42	7.5	.32	7.7	5.20	7.7	1.51	7.9	2.70	8.0	....	....
May 21	....	6.9	....	6.7	....	6.5	....	7.2	....	....	....	7.1	....	....
May 28	2.60	7.5	.25	6.9	.45	7.2	6.20	7.1	5.40	7.6	1.40	7.6	....	....
June 4	.25	7.1	.22	7.0	.23	7.2	2.20	7.3	4.50	7.5	.81	7.3	....	....
June 11	.15	....	.15	....	.40	....	3.00	....	4.30	....	.40	....	....	....
June 18	.31	....	.22	....	.43	....	2.58	....	4.90	....	.90	....	....	....
July 9	.14	6.9	.20	7.2	.41	7.6	.84	7.7	.58	7.1	.32	6.8	....	....
July 16	.15	....	.19	....	.35	....	.70	....	.25	....	.12	....	....	....
July 23	.10	....	.15	....	.25	6.8	.15	....	.18	6.6	.15	6.6	....	....
July 30	.15	6.4	.14	6.7	.32	6.7	.34	6.8	.52	6.9	.15	6.5	....	....
Aug. 6	.10	6.0	.01	6.2	.15	6.4	.08	6.6	.10	6.6	.07	6.4	....	....
Aug. 2	.12	6.0	.14	6.1	.22	6.8	.31	6.5	.65	7.5	.15	6.5	....	....
Sept. 3	.10	6.8	.16	6.6	.25	7.0	.50	7.5	.64	7.5	.17	6.9	....	....
Sept. 17	.10	7.0	.20	7.0	.37	7.7	2.95	7.7	2.75	7.8	.19	7.3	1.8	7.9
Sept. 24	.14	6.0	.24	6.5	.32	6.9	.62	6.5	1.18	6.6	.25	7.5	.89	6.8
Oct. 1	<.10	6.0	<.10	5.9	.32	6.8	.36	6.5	.45	6.4	.15	6.4	.40	6.9
Oct. 29	.20	7.8	.25	7.6	.31	7.4	2.10	8.0	4.50	7.7	.60	7.7	2.02	8.1
Nov. 5	.21	7.9	.26	7.6	.29	7.4	2.60	7.5	4.20	7.6	.54	7.8	2.35	7.8
Nov. 19	.24	7.3	.30	7.7	.33	7.4	4.00	7.6	4.20	7.7	.46	7.3	3.15	7.6
Dec. 3	.18	7.1	.24	7.2	.74	6.1	2.18	7.2	4.10	7.6	1.00	7.4	2.50	7.0
Dec. 17	.18	6.5	.21	6.1	.38	6.9	2.80	6.6	3.42	6.8	.77	7.1	2.61	7.4
Dec. 31	.20	7.7	.30	7.4	.30	7.5	1.40	7.5	3.10	7.3	....	....	2.20	7.5
Average	0.26	7.1	0.22	7.0	0.34	7.1	2.59	7.3	2.9	7.4	0.79	7.3	1.99	7.4

[1] 1=Watershed W-3, Taylor Creek at S.R. 68, 2=Little Bimini Creek at Potter Rd., 3=watershed W-13, Otter Creek at Potter Rd. (S-13), 4=Williamson Main Ditch, 5=Williamson East Lateral Ditch. 6=watershed W-2A, Taylor Creek at U.S. Highway 441, 7=watershed, Williamson Ditch at S-7.

Table A-31.—Nitrate-nitrogen (N) and orthophosphate-phosphorus (P) concentrations (mg/l), Taylor Creek watershed, 1975

	Concentrations at site No.[1]—													
	1		2		3		4		5		6		7	
Date	N	P	N	P	N	P	N	P	N	P	N	P	N	P
Jan. 14	<0.02	0.05	<0.004	0.41	0.76	1.29	<0.004	<0.003	0.04	<0.006	0.04	0.006	0.18	0.63
Feb. 4	.06	.12	.60	.65	.81	1.50	......	.04	.10	.05	.54	.28	.51	
Feb. 18	.04	.17	.70	.87	.74	1.55	.13	.09	.02	.09	.11	.54	.17	.15
Mar. 3	.12	.12	.80	.54	.72	1.78	.21	.11	.36	1.01	.18	.47	.36	.49
Mar. 18	.17	.09	.24	.54	.72	1.23	.23	.12	.16	.18	.12	.76	.40	.19
Apr. 1	.09	.08	.19	.55	.43	1.50	.10	.09	.07	.10	.15	.58	.34	.28
Apr. 15	.23	<.06	.21	.42	.62	2.70	.13	.09	.16	<.06	.22	.28	.17	.38
Apr. 29	.34	<.06	.17	.35	.43	1.40	.18	<.06	.24	<.06	.30	.39	.19	.48
May 13	.19	.07	.40	.34	.45	1.49	.21	.07	.28	.07	.23	.59	.28	.49
May 27	.05	.06	.07	.21	.58	2.43	<.04	<.06	.04	<.06	<.04	.30	<.04	.55
June 10	.04	.06	.41	.33	.09	<3.26	<.04	.18	<.04	.07	<.04	.40	.05	.52
June 24	.07	.16	.18	1.01	.15	1.35	.04	.07	.05	.35	.06	.69	.05	.12
July 1	.12	.25	1.29	.76	.27	2.35	.07	.18	.06	.23	<.04	.64	.06	.22
July 8	.06	.12	1.25	.66	<.04	2.26	<.04	.16	<.04	.39	<.04	.47	<.04	.26
July 15	.04	.33	.30	1.26	.05	.78	.16	.11	.06	.30	<.04	.49	.11	.28
July 22	.23	.66	1.23	1.75	.07	2.02	.08	.28	.07	.57	.04	.67	.07	.45
July 29	.23	.30	1.05	1.10	.06	1.75	.09	.15	.04	.31	.04	.48	.07	.25
Aug. 5	.40	.43	.88	.62	.11	1.37	.21	.16	.13	.23	.17	.46	.09	.36
Aug. 12	.28	.68	.64	.95	.11	1.42	.09	.15	.10	.22	.13	.35	.15	.24
Aug. 19	.24	.75	1.02	.65	.04	1.72	<.04	.16	<.04	.33	<.04	.79	<.04	.23
Aug. 26	.22	.58	.72	.62	.10	2.83	<.04	.05	<.04	.19	<.04	.73	.04	.22
Sept. 2	.14	.22	.70	.66	.04	2.77	.16	.10	<.04	.06	<.04	.81	.06	.10
Sept. 9	.11	.13	.66	.40	.05	1.43	.05	.13	.04	.34	.03	.61	.05	.25
Sept. 16	.07	.10	.40	.63	.03	1.60	.19	.15	.05	.45	.14	.39	.25	.32
Sept. 23	.11	.51	.98	1.63	.62	2.90	.14	.70	.05	.46	.27	1.42	.14	.57
Sept. 30	.06	.65	.57	2.23	.74	3.06	.09	.65	.13	1.32	1.20	2.26	.24	.89
Oct. 7	.06	.44	1.14	1.35	.23	5.56	.38	.39	.06	.75	.91	1.27	.48	.60
Oct. 14	.13	.37	1.18	.87	.12	4.07	.22	.26	.06	.45	<.04	1.44	.05	.73
Oct. 21	.07	.44	1.02	1.08	1.51	3.02	.17	.38	.09	.47	.74	1.68	.39	.39
Oct. 28	.16	.49	1.27	.89	.43	3.21	.16	.36	.05	.35	<.04	1.07	.05	1.04
Nov. 4	.07	.60	.67	1.65	.43	4.24	.17	.31	.04	.24	.23	.67	......	....
Nov. 11	.14	.49	1.02	2.18	.14	3.23	.08	.24	<.04	.37	<.04	.69	......	....
Nov. 18	.14	.21	1.22	.65	.30	2.66	<.04	.13	<.04	.09	.09	.22	......	....
Nov. 25	.08	.16	.90	.74	.67	2.02	.04	.23	<.04	.08	.05	.59	......	....
Dec. 3	.12	.27	.56	1.62	.96	2.13	<.04	.10	<.04	.06	<.04	.99	.05	.08
Dec. 9	.31	.18	.48	.62	.59	2.13	.25	.11	.17	.09	.36	.97	.35	.16
Dec. 16	.27	.18	.47	1.04	.73	2.02	.25	.09	.27	.06	.35	.75	.30	.13
Dec. 23	.06	.10	.39	.65	.47	2.94	.06	.07	.06	.07	.11	.64	.07	.07
Dec. 30	.07	.16	.30	1.34	.06	3.91	.04	.08	.05	<.06	.14	.63	......	....
Average	0.14	0.28	0.67	0.89	0.40	2.33	0.12	0.18	0.09	0.27	0.18	0.71	0.17	0.37

[1] 1=Watershed W-3, Taylor Creek at S.R. 68; 2=Little Biminy Creek at Potter Rd.; 3=watershed W-13, Otter Creek at Potter Rd. (S-13); 4=Williamson Main Ditch; 5=Williamson East Lateral Ditch; 6=watershed W-2A, Taylor Creek at U.S. Highway 441; 7=watershed W-5, William Ditch at S-7; 8=Taylor Creek at well-line "B"; 9=Otter Creek at U.S. Highway 441; 10=Otter Creek at S.R. 68; 11=Otter Creek at Otter Creek Rd.; 12=Mosquito Creek at S.R. 710; 13=Nubbin Slough at S.R. 710; 14=Mosquito Creek at S.R. 70.

8		9		10		11		12		13		14	
N	P	N	P	N	P	N	P	N	P	N	P	N	P
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
0.17	0.80	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
.04	.42	....	....	....	....	....	....	....	....	....	....	....	....
<.04	.26	....	....	....	....	....	....	....	....	....	....	....	....
<.04	.30	....	....	....	....	....	....	....	....	....	....	....	....
.04	.82	....	....	....	....	....	....	....	....	....	....	....	....
.06	.65	....	....	....	....	....	....	....	....	....	....	....	....
<.04	.52	....	....	....	....	....	....	....	....	....	....	....	....
.08	.56	....	....	....	....	....	....	....	....	....	....	....	....
.09	.84	....	....	....	....	....	....	....	....	....	....	....	....
.12	.42	....	....	....	....	....	....	....	....	....	....	....	....
.11	.39	....	....	....	....	....	....	....	....	....	....	....	....
.14	.47	....	....	....	....	....	....	....	....	....	....	....	....
.08	.77	....	....	....	....	....	....	....	....	....	....	....	....
.09	1.05	....	....	....	....	....	....	....	....	....	....	....	....
.05	.36	....	....	....	....	....	....	....	....	....	....	....	....
.12	.37	....	....	....	....	....	....	....	....	....	....	....	....
.47	1.07	....	....	....	....	....	....	....	....	....	....	....	....
.87	1.52	0.58	2.56	0.83	2.59	0.64	2.54	....	....	....	....	....	....
1.35	2.23	.39	2.98	1.00	3.02	.90	3.02	....	....	....	....	....	....
.83	.91	.22	3.58	.37	5.17	.28	4.79	....	....	....	....	....	....
.43	1.32	.26	3.45	.14	4.58	.07	3.19	....	....	....	....	....	....
....	....	.28	3.61	1.55	4.12	1.18	4.60	....	....	....	....	....	....
....	....	.67	3.13	.32	3.85	.26	3.94	1.95	2.13	0.06	6.11	0.08	1.68
....	....	.80	3.31	.27	6.01	.21	4.66	1.49	3.23	.06	2.95	.11	3.02
....	....	.58	1.96	2.23	3.24	.06	2.37	....	....	....	....	....	....
....	....	.73	.81	.43	3.45	.20	2.06	2.26	2.48	.21	1.27	.17	3.93
....	....	.96	.99	.77	3.02	.55	3.02	....	....	....	....	....	....
....	....	1.25	.98	.36	3.02	.29	1.79	2.00	3.02	.08	3.02	.14	3.91
....	....	1.41	.86	.24	3.02	.35	2.44	....	....	....	....	....	....
....	....	1.52	.99	.52	3.02	.51	3.21	2.32	4.66	.26	1.81	.35	4.22
....	....	.92	.70	.05	3.02	.50	2.64	....	....	....	....	....	....
....	....	1.15	.66	.06	3.41	.21	3.59	3.62	4.79	.70	1.89	.50	4.59
0.25	0.76	0.78	2.04	0.61	3.64	0.41	3.19	2.27	3.38	0.23	2.84	0.22	3.56

Table A-32.—Electrical conductivity (EC, μmhos/cm) and pH, Taylor Creek Watershed, 1975

	EC and pH at site No.[1]—													
	1		2		3		4		5		6		7	
Date	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH
Jan. 14	0.20	7.1	0.25	7.0	0.38	7.3	2.60	7.4	3.80	7.2	1.20	7.1	2.30	7.1
Feb. 4	.30	7.6	.25	7.5	.27	7.0	1.20	7.9	3.60	8.0	1.10	......	2.90	7.5
Feb. 18	.30	7.3	.30	7.3	.40	7.6	3.90	7.9	4.50	8.0	1.00	7.7	3.20	7.9
Mar. 3	.25	7.4	.25	7.3	.29	7.3	2.80	7.7	1.80	7.4	1.40	7.2	1.80	7.6
Mar. 18	.42	7.5	.35	7.4	.39	7.6	2.90	7.6	4.00	7.4	1.20	7.2	2.90	7.6
Apr. 1	.28	7.3	.18	6.6	.28	6.8	5.60	7.6	3.90	7.8	1.00	6.7	4.40	7.4
Apr. 15	.26	7.2	.21	7.2	.34	7.5	5.90	7.5	5.30	7.6	1.70	7.3	4.50	7.3
Apr. 29	.24	7.0	.20	6.7	.39	6.6	6.00	7.2	5.00	7.4	1.50	7.2	4.80	7.6
May 13	.30	7.2	.23	7.1	.34	7.1	5.10	6.5	4.50	7.3	2.10	7.4	3.60	7.2
May 27	.25	7.8	.15	6.7	.35	7.4	5.50	7.1	4.50	7.2	1.70	7.0	3.60	6.9
June 10	.33	7.6	.25	7.2	.51	7.2	4.60	7.6	4.80	7.4	2.20	7.5	3.50	7.6
June 24	.26	6.6	.35	6.7	1.08	7.0	2.70	7.7	3.10	7.3	.72	7.7	3.20	7.3
July 1	.25	6.7	.27	7.1	.70	6.8	2.10	7.2	1.70	7.2	.45	7.1	1.90	7.1
July 8	.28	7.1	.35	7.4	.52	6.9	3.10	7.8	2.60	7.5	.75	7.1	2.40	7.2
July 15	.12	6.8	.20	6.7	.65	6.7	1.08	7.1	1.15	7.0	.45	6.9	.82	7.0
July 22	.10	6.9	.28	6.9	.35	7.6	1.15	7.4	1.12	7.2	.25	7.3	1.08	7.1
July 29	.11	6.9	.20	7.1	.28	6.8	.84	7.5	1.07	7.5	.24	6.9	.78	7.2
Aug. 5	.20	7.0	.30	7.0	.35	6.8	1.70	7.6	1.35	7.4	.40	7.3	1.00	7.3
Aug. 12	.15	6.8	.24	7.0	.18	7.1	.82	7.1	1.18	7.5	.35	7.6	.92	7.4
Aug. 19	.15	6.8	.35	7.1	.40	6.7	1.30	7.0	1.65	7.0	.25	6.6	1.35	6.9
Aug. 26	.15	6.7	.30	7.1	.43	6.9	1.65	7.1	1.90	7.0	.33	6.6	1.40	6.8
Sept. 2	.20	6.8	.30	6.9	.39	6.8	1.25	7.0	3.70	7.5	.25	6.6	2.70	7.0
Sept. 9	.14	6.9	.21	7.0	.33	6.9	.65	7.1	1.56	7.1	.17	6.7	.98	7.0
Sept. 16	.28	7.1	.25	6.9	.52	6.9	1.10	7.1	2.50	7.0	.25	6.7	1.60	6.9
Sept. 23	.10	6.9	.25	7.2	.62	6.9	.38	6.9	.25	6.5	.28	6.8	.30	6.7
Sept. 30	.15	6.7	.22	6.7	.40	6.9	.29	6.7	.78	6.7	.25	6.7	.37	6.8
Oct. 7	.15	6.2	.28	7.0	.52	7.4	.88	7.2	1.70	7.3	.33	7.2	1.05	7.2
Oct. 14	.15	6.9	.30	7.0	.45	7.1	1.50	7.3	2.20	7.3	.30	6.7	1.10	7.0
Oct. 21	.15	7.0	.25	7.0	.45	7.3	.50	6.9	1.70	7.0	.33	6.7	.62	6.9
Oct. 28	.15	7.1	.25	7.1	.40	7.0	1.45	7.4	3.20	7.2	.45	7.0	1.00	7.0
Nov. 4	.13	6.9	.25	6.9	.40	7.0	1.70	7.3	3.60	7.3	.25	6.9	......	......
Nov. 11	.15	7.3	.20	7.3	.28	7.2	1.50	7.8	3.10	7.7	.19	7.0	......	......
Nov. 18	.20	6.7	.30	7.2	.38	6.9	2.40	8.1	4.90	7.6	.60	7.2	......	......
Nov. 25	.20	7.4	.30	7.4	.35	7.2	3.10	7.8	4.30	7.6	.80	7.2	......	......
Dec. 3	.30	7.0	.30	7.3	.30	7.0	2.20	7.9	5.00	7.6	.45	7.2	2.80	7.7
Dec. 9	......	7.9	......	7.4	......	7.0	......	7.9	......	7.7	......	7.4	......	7.8
Dec. 16	.29	7.3	.30	7.5	.32	7.1	3.00	7.9	5.00	7.5	.90	7.5	3.40	7.5
Dec. 23	.25	7.4	.30	7.7	.35	7.0	2.80	7.8	4.00	7.7	1.20	7.3	2.90	7.8
Dec. 30	.25	7.5	.33	7.4	.40	7.0	2.70	7.9	4.50	7.6	1.20	7.4	......	......
Average	0.21	7.1	0.26	7.1	0.41	7.1	2.37	7.4	3.01	7.4	0.75	7.1	2.16	7.2

[1] 1=Watershed W-3, Taylor Creek at S.R. 68; 2=Little Biminy Creek at Potter Rd.; 3=watershed W-13, Otter Creek at Potter Rd. (S-13); 4=Williamson Main Ditch; 5=Williamson East Lateral Ditch; 6=watershed W-2A, Taylor Creek at U.S. Highway 441; 7=watershed W-5, William Ditch at S-7; 8=Taylor Creek at well-line "B"; 9=Otter Creek at U.S. Highway 441; 10=Otter Creek at S.R. 68; 11=Otter Creek at Otter Creek Rd.; 12=Mosquito Creek at S.R. 710; 13=Nubbin Slough at S.R. 710; 14=Mosquito Creek at S.R. 70.

8		9		10		11		12		13		14	
EC	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
0.52	7.6	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
1.60	7.4	....	....	....	....	....	....	....	....	....	....	....	....
2.80	7.2	....	....	....	....	....	....	....	....	....	....	....	....
2.40	7.6	....	....	....	....	....	....	....	....	....	....	....	....
.48	6.9	....	....	....	....	....	....	....	....	....	....	....	....
.50	7.0	....	....	....	....	....	....	....	....	....	....	....	....
.63	7.2	....	....	....	....	....	....	....	....	....	....	....	....
.30	6.9	....	....	....	....	....	....	....	....	....	....	....	....
.23	6.8	....	....	....	....	....	....	....	....	....	....	....	....
.25	7.0	....	....	....	....	....	....	....	....	....	....	....	....
.30	7.4	....	....	....	....	....	....	....	....	....	....	....	....
.25	7.1	....	....	....	....	....	....	....	....	....	....	....	....
.20	6.7	....	....	....	....	....	....	....	....	....	....	....	....
.25	6.8	....	....	....	....	....	....	....	....	....	....	....	....
.25	6.7	....	....	....	....	....	....	....	....	....	....	....	....
.22	6.6	....	....	....	....	....	....	....	....	....	....	....	....
.15	6.6	....	....	....	....	....	....	....	....	....	....	....	....
.23	6.9	0.65	6.8	0.68	6.9	0.65	7.2	....	....	....	....	....	....
.20	6.6	.35	6.7	.42	6.8	.41	6.9	....	....	....	....	....	....
.25	6.8	.50	7.1	.59	7.1	.50	7.3	....	....	....	....	....	....
.35	6.8	.45	6.9	.50	7.2	0.45	7.1	....	....	....	....	....	....
....	....	.35	7.0	.41	7.0	.40	7.3	....	....	....	....	....	....
....	....	.40	7.1	.45	7.1	.40	7.0	0.60	7.4	0.60	7.0	0.55	7.2
....	....	.40	6.9	.45	7.0	.43	7.3	.60	7.3	.62	7.1	.70	7.2
....	....	.39	7.4	.44	7.2	.38	7.3	....	....	....	....	....	....
....	....	.35	6.8	.44	7.1	.35	7.0	1.00	7.3	.52	7.0	.70	7.1
....	....	.39	7.0	.45	6.9	.36	7.2	....	....	....	....	....	....
....	....	.42	7.0	.40	7.4	.35	6.8	.70	7.5	.35	7.0	.70	7.3
....	....	....	7.1	....	6.9	....	7.1	....	....	....	....	....	....
....	....	.50	7.1	.46	7.2	.35	7.1	.80	7.5	.42	7.0	.80	7.3
....	....	.38	7.2	.45	7.0	.37	6.9	....	....	....	....	....	....
....	....	.41	6.9	.46	7.0	.40	6.7	.80	7.7	.42	6.9	1.00	7.4
0.59	7.0	0.42	7.0	0.47	7.1	0.41	7.1	0.75	7.4	0.49	7.0	0.74	7.2